IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

TOT POWER CONTROL, S.L., Plaintiff, v. T-MOBILE US, INC., AND T-MOBILE USA, INC., Defendants.	Civil Action No. 6:21-cv-00109 The Honorable ____________________ **JURY TRIAL DEMANDED**

COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff TOT Power Control, S.L. ("TOT") hereby asserts the following claims for patent infringement of United States Patent Numbers 7,496,376 ("the '376 Patent") and 7,532,865 ("the '865 Patent") (collectively, "the Patents-in-Suit") against Defendants T-Mobile US, Inc., and T-Mobile USA, Inc. (collectively "Defendants"), and alleges as follows:

NATURE OF THE ACTION

1. This is an action for patent infringement under the Patent Laws of the United States, 35 U.S.C. § 1, *et seq*., seeking damages and other relief under 35 U.S.C. § 281, *et seq*.

PARTIES

2. TOT is a limited liability company organized and existing under the laws of Spain with its principal place of business at C/ Gobelas 17, 1st floor, Urb. La Florida 28023 Madrid, Spain.

3. T-Mobile US, Inc. is a Delaware corporation with its principal place of business at 12920 SE 38th Street, Bellevue, Washington 98006. T-Mobile US, Inc. does business in the State of Texas and in this judicial district. T-Mobile US, Inc. may be served with process through its registered agent, Corporation Service Company, 211 East 7th Street, Suite 620, Austin, Texas, 78701-3218.

4. T-Mobile USA, Inc. is a Delaware corporation with its principal place of business at 12920 SE 38th Street, Bellevue, Washington 98006. T-Mobile USA, Inc. does business in the State of Texas and in this judicial district. T-Mobile USA, Inc. may be served with process through its registered agent, Corporation Service Company, 211 E. 7th Street, Suite 620, Austin, Texas 78701.

JURISDICTION AND VENUE

5. This is an action for patent infringement arising under the Patent Laws of the United States, Title 35 of the United States Code.

6. This Court has subject matter jurisdiction over this action pursuant to 28 U.S.C. §§ 1331 and 1338(a) because the action concerns the infringement of U.S. patents.

7. Defendants are subject to this Court's specific and general personal jurisdiction because they conduct substantial business in the Western District of Texas, directly and/or through intermediaries, including: (i) committing at least a portion of the acts of infringement alleged herein in this judicial district, and (ii) regularly conducting or soliciting business in this district, engaging in other persistent courses of conduct in this judicial district including maintaining continuous and systematic contacts in this judicial district, and availing themselves of the privileges of doing business in this judicial district.

8. Defendants offer postpaid and prepaid wireless voice, messaging, and data service to customers in all U.S. states and territories, including in the Western District of Texas. In connection with their provision of wireless products and services, Defendants offer Code Division Multiple Access ("CDMA") network services directly to customers (through retail stores and their websites) and to dealers and third-party distributors for resale through independent, third-party retail outlets and third-party websites.

9. Defendants have a physical presence in the District, including, but not limited to, ownership of or control over property, inventory, infrastructure, or people. For example,

Defendants operate numerous retail stores in this District, including stores at 100 North New Road, Suite 110, Waco, Texas 76710; 2448 West Loop 340, Suite 24A, Waco, Texas 76711; and 208 Hewitt Drive, #200, Waco, Texas 76712. Additionally,

10. Venue is proper in this District pursuant to 28 U.S.C. § 1400(b). Defendants maintain a regular and established place of business in this District, including by maintaining or controlling retail stores in this District and by maintaining CDMA-based wireless networks in this District, including on cellular towers and other installation sites owned or leased by Defendants. Defendants transact business in this District and purposefully direct their business activities, including the installation, maintenance, and use of the infringing telecommunications equipment, to this District.

BACKGROUND

11. Wideband CDMA ("WCDMA") is the physical layer implementation of the 3rd Generation Partnership Project ("3GPP") Universal Mobile Telephone Service ("UMTS") cellular standard. In WCDMA, a single frequency channel is utilized to transmit voice calls and data between multiple user equipment ("UE") and a base transmission station ("BTS") consisting of a Radio Network Controller ("RNC") and at least one Node-B. Each UE is assigned a code that is transmitted in the RF channel with the codes for other UE. The codes are close to, but not perfectly, orthogonal. This results in a certain degree of interference between codes in the same RF channel. For at least this reason, power control is a critical aspect of WCDMA systems. Power control is used to alleviate the near-far intracell interference problem—interference resulting from the transmission power requirements of UE near to and UE far from the Node-B. The 3GPP UMTS standard defines closed loop power control between the BTS and the UE in both the uplink (UE transmitting to BTS) and the downlink (BTS transmitting to UE). The first of the closed loop

controls is inner loop power control. In the uplink, a signal-to-interference ratio target (SIR_{Target}) is set in the BTS. As the signal is received at the BTS, per the 3GPP UMTS standard, the SIR is measured and compared to the SIR_{Target}. For example, the SIR measurement is dictated in § 5.2.2 of ETSI TS 25.215, *Physical layer - Measurements (FDD):*

Definition	Type 1: Signal to Interference Ratio, is defined as: (RSCP/ISCP)×SF. The measurement shall be performed on the DPCCH of a Radio Link Set. In compressed mode the SIR shall not be measured in the transmission gap. The reference point for the SIR measurements shall be the Rx antenna connector. If the radio link set contains more than one radio link, the reported value shall be the linear summation of the SIR from each radio link of the radio link set. If Rx diversity is used in the Node B for a cell, the SIR for a radio link shall be the linear summation of the SIR from each Rx antenna for that radio link. When cell portions are defined in the cell, the SIR measurement shall be possible in each cell portion. where: RSCP = Received Signal Code Power, unbiased measurement of the received power on one code. ISCP = Interference Signal Code Power, the interference on the received signal. SF=The spreading factor used on the DPCCH. Type 2: Signal to Interference Ratio, is defined as: (RSCP/ISCP)×SF. The measurement shall be performed on the PRACH control part. The reference point for the SIR measurements shall be the Rx antenna connector. When cell portions are defined in the cell, the SIR measurement shall be possible in each cell portion. where: RSCP = Received Signal Code Power, unbiased measurement of the received power on the code. ISCP = Interference Signal Code Power, the interference on the received signal. SF=The spreading factor used on the control part of the PRACH.

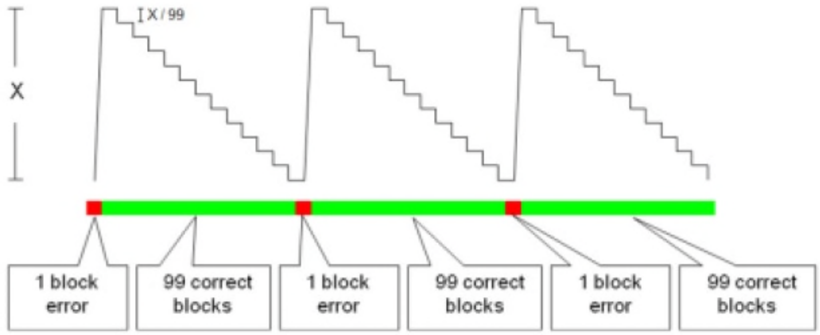
(https://www.etsi.org/deliver/etsi_ts/125200_125299/125215/11.00.00_60/ts_125215v110000p.pdf; last accessed Jan. 28, 2021.)

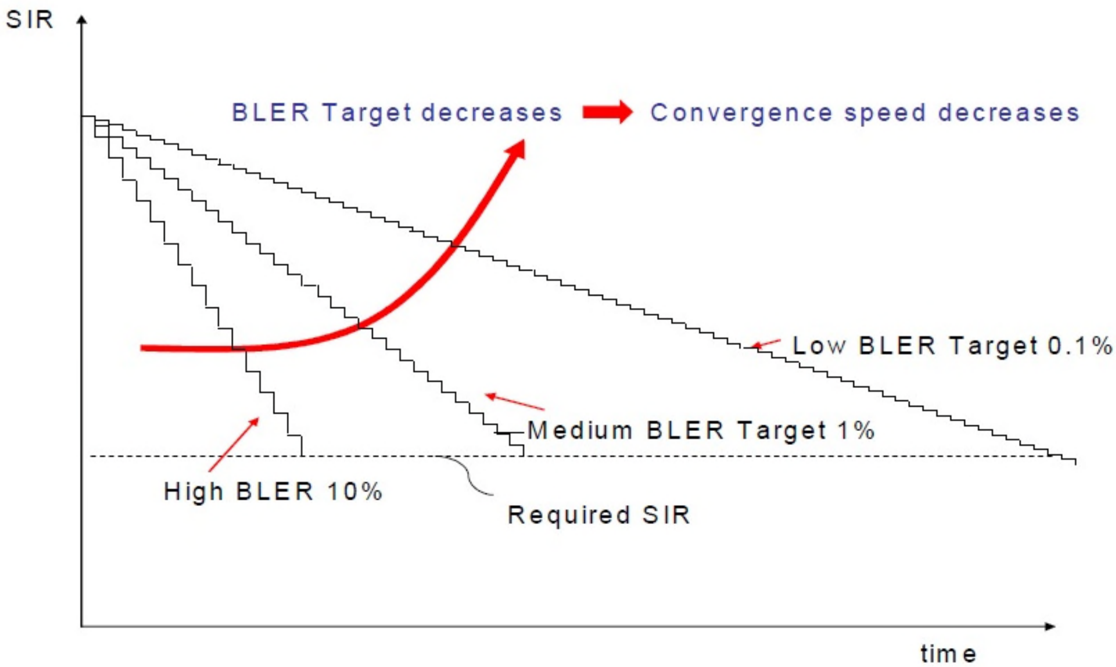
In the uplink, if the measured SIR is below the SIR_{Target}, the BTS sends a TPC command to the UE to increase the transmission power. If the measured SIR is above the SIR_{Target}, the BTS sends a TPC command to the UE to decrease the transmission power. The downlink works similarly with SIR measurements made at the UE and TPC power control commands sent to the BTS. For example, the inner loop power control is dictated in § 5.1.2.2.1 of ETSI TS 25.214, *Physical layer procedures (FDD):*

> 5.1.2.2 Ordinary transmit power control
>
> 5.1.2.2.1 General
>
> For each activated uplink frequency, the uplink inner-loop power control adjusts the UE transmit power in order to keep the received uplink signal-to-interference ratio (SIR) on that frequency at a given SIR target, SIR_{target}.
>
> The cells in the active set should estimate signal-to-interference ratio SIR_{est} of the received uplink DPCH. The cells in the active set should then generate TPC commands and transmit the commands once per slot according to the following rule: if $SIR_{est} > SIR_{target}$ then the TPC command to transmit is "0", while if SIR_{est} < SIRtarget then the TPC command to transmit is "1".

(https://www.etsi.org/deliver/etsi_ts/125200_125299/125214/11.03.00_60/ts_125214v110300p.pdf; last accessed Jan. 28, 2021.)

12. The 3GPP UMTS standard also defines outer loop power control for maintaining the "long-term quality control of the radio channel." (ETSI TS 25.401, § 7.2.4.8.1 at 23, *UTRAN overall description*; https://www.etsi.org/deliver/etsi_ts/125400_125499/125401/04.02.00_60/ts_125401v040200p.pdf; last accessed Jan. 28, 2021.) through adjustments to the SIR_{Target} value. The 3GPP UMTS standard does not define the specifics of the outer loop power control algorithm. The early universal approach to the adjustment of SIR_{Target} values is based on block/frame errors indicated by Cyclic Redundancy Check ("CRC") errors. When a CRC error is detected, the SIR_{Target} is increased by a number of decibels. For each successive block/frame without a CRC error, the SIR_{Target} value is decreased by a percentage corresponding to the Block Error Rate ("BLER") percentage that the system is configured for. This process of adjusting the SIR_{Target} value is illustrated in the first figure below, with an exemplary BLER of 1%. The second figure below shows the rate at which the SIR_{Target} value is decreased for BLER values ranging from 10% to 0.1%.





13. Under steady state conditions, the convergence rate of the SIR_{Target} value based on the CRC and BLER is slow and potentially wastes significant potential capacity within a RF channel, particularly a channel with dynamic signal to interference characteristics. Furthermore, this problem is particularly acute in the situation of “wind-up,” where large increases in the SIR_{Target} occur. “Wind-up” results from significant degradation in the conditions of the wireless channel, for example, from the UE entering a tunnel or elevator, rapid changes in UE speed, or significant weather interference. The Patents-in-Suit are directed at better management of the SIR_{Target} values so that power, and consequently wireless channel capacity, is not wasted and call quality is

maintained. This is achieved by the techniques taught and claimed in the ’376 Patent which is directed at a more precise manner of adjusting the SIR_{Target} under a variety of steady state and dynamic channel conditions; and in the ’865 Patent which is directed at managing control power when coming out of the “wind-up” situation, also known as “unwinding.”

PATENTS-IN-SUIT

Background

14. On February 24, 2009, the United States Patent and Trademark Office duly and legally issued the ’376 Patent, entitled “Outer Loop Power Control Method and Apparatus for Wireless Communications Systems” to Alfonso Campo Camacho, Miguel Blanco Carmona, Luis Mendo Tomas, José M. Hernando Rabanos, and Alvaro Lopez Medrano. A copy of the ’376 Patent is attached hereto as Exhibit 1.

15. TOT owns all substantial right, title, and interest in the ’376 Patent, and holds the right to sue and recover damages for infringement thereof, including past infringement.

16. The ’376 Patent describes and claims an outer loop power control apparatus for tackling the problems that are associated with fading in the wireless channel by (i) measuring the amount of fading within the channel and (ii) accounting for that fading as part of the outer loop power control. Channel fading can occur as the result of a variety of conditions, e.g., multipath propagation, referred to as multipath-induced fading, weather (particularly rain), or shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. In accordance with the 3GPP standard, as part of the inner loop power control, the measured received SIR value (SIR_{Rec}) is compared with an established desired signal to interference ratio value (SIR_{Target}) to determine whether a TPC power command should be sent to the UE (in uplink communications) or to the BTS (in downlink communications) to increase or

decrease power output. In general, if the SIR_{Rec} is less than SIR_{Target}, a TPC command will be sent (from BTS to UE in uplink, from UE to BTS in downlink) to increase power output; and if the SIR_{Rec} is greater than SIR_{Target}, a TPC command will be sent to decrease power output.

17. The ’376 Patent describes and claims a technique to determine the SIR_{Target} values based on the collection of SIR_{Rec} values. These SIR_{Rec} values are used to calculate the short-term historical conditions in the channel (which will affect the received signal as judged by the signal-to-interference, SIR, at the receiver). Based on the historical conditions, one or more fading margin(s) can be calculated. A weighting function is then used to map the fading margins to a SIR_{Target} value, taking into account prior SIR_{Target} values. This approach allows the SIR_{Target} value to vary with channel conditions and reduce the amount of data errors that occur because of the channel conditions. This, in turn, reduces the amount of power that is wasted using the traditional power control techniques based on data errors.

18. On May 12, 2009, the United States Patent and Trademark Office duly and legally issued the ’865 Patent, entitled “Outer Loop Power Control Method and Device for Wireless Communications Systems” to Alfonso Campo Camacho, Miguel Blanco Carmona, Luis Mendo Tomas, José M. Hernando Rabanos, and Alvaro Lopez Medrano. A copy of the ’865 Patent is attached hereto as Exhibit 2.

19. TOT owns all substantial right, title, and interest in the ’865 Patent, and holds the right to sue and recover damages for infringement thereof, including past infringement.

20. The ’865 Patent describes and claims a technique to solve the problem of convergence of the SIR_{Target} value when the exit from a “wind-up” condition has started, i.e., when the unwinding process has started. The technique of the ’865 Patent matches the SIR_{Target} value at wind-up exit to a value close to the SIR_{Target} value before the wind-up began. By doing so, the unwinding time

of the SIR_{Target} value is drastically shortened and interference in the WCDMA system is reduced. The immediate effect is that the outer loop power control continues within the normal mode of steady state operation. The solution of the ’865 Patent thus provides for increased system capacity and the quality of wireless connections (e.g., reduction in dropped calls).

21. The Patents-in-Suit describe and claim techniques for better management of the SIR_{Target} values so that power, and consequently wireless channel capacity, are not wasted and call quality is maintained. TOT shared the techniques of the Patents-in-Suit with Defendants’ base station equipment suppliers, including Nokia and Ericsson, who surreptitiously adopted the patented techniques of Patents-in-Suit without approval, authority, or license to do so. As a result of the base station equipment suppliers implementing the patented techniques of the Patents-in-Suit, and Defendants’ implementation of that equipment and TOT’s patented techniques in their networks, Defendants achieve significant capacity gains in their WCDMA-based wireless networks.

22. The claims of the Patents-in-Suit are not directed to abstract ideas and are not merely attempting to limit a method of organizing human activity or an idea itself to a particular technological environment. The claimed technologies are expressly directed to the structure and operation of wireless communication networks, which are not abstract methods or abstract ideas. The apparatus and methods claimed in the Patents-in-Suit exist only in a concrete and tangible form, and the claimed inventions cannot be accomplished through pen-and-paper or the human mind. As alleged above, the claimed apparatus and methods provided a technical solution to an existing technical problem. Accordingly, the claims of the Patents-in-Suit are not directed to an abstract idea.

23. When viewed as a whole, the claims of the Patents-in-Suit, including as an ordered combination, are not merely a recitation of well-understood, routine, or conventional technologies

or components. The claimed inventions were not well-known, routine, or conventional at the time of the inventions and represent specific improvements over the prior art and existing systems and methods. The claimed technologies were not known in the prior art at the time of the invention, let alone well-known, routine, or conventional.

24. Claim 6 of the '376 Patent recites:

> An outer loop power control apparatus for wireless communications systems, comprising at least one programmable electronic device the programmable electronic device operable to, based on a data signal received from a base station or from a mobile station, perform the steps of: establishing a target block error rate ($BLER_{target}$), calculating an estimate (701) of a desired signal to interference ratio (SIR_{rec}) and of some fading parameters in a channel (706) which characterize the data signal (107, 108) received, estimating some fading margins (M_1, M_2, . . . , M_N) associated with some outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and with the fading parameters in the channel (706), indicating a status of the data blocks (707) based on the checking of a Cyclic Redundancy Code (CRC), and establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (707), the fading margins (M_1, M_2, M_N) and the target block error ($BLER_{target}$) of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (107, 108).

25. Claim 1 of the '865 Patent recites:

> Outer loop power control method for wireless communications systems, based on CDMA technology, the method comprising: estimating a desired signal to interference ratio received (SIR_{rec}) based on a data signal (107.108) received from a base station (102, 103) or mobile station (104), setting a desired signal to interference ratio target (SIR_{target}) that is close to a signal to interference ratio required (SIR) during the normal mode of the outer loop, detecting a start (402) of the outer loop wind-up, setting a specific desired signal to interference ratio target (SIR_{target}) during the outer loop wind-up, and detecting a start (403) of the outer loop unwinding, wherein the desired signal to interference ratio target (SIR_{target}) is modified at the start (403) of the outer loop unwinding, to match it to the outer loop power control in normal mode just prior to the start of the outer loop wind up.

COUNT I
(INFRINGEMENT OF THE '376 PATENT)

26. TOT repeats and re-alleges the allegations of Paragraphs 1–25 above as if fully set forth herein.

27. Defendants have infringed and continue to infringe one or more claims of the ’376 Patent, including but not limited to Claims 1 and 6, pursuant to 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by using the patented apparatus and methods of the ’376 Patent in the United States without authority as part of the implementation of their WCDMA-based wireless networks.

28. Defendants have directly infringed the ’376 Patent and are thus liable for infringement of the ’376 Patent pursuant to 35 U.S.C. § 271. TOT has suffered, and continues to suffer, damages because of Defendants’ infringement of the ’376 Patent. TOT is entitled to recover from Defendants the damages adequate to compensate for such infringement, which have yet to be determined.

29. As just one non-limiting example, Defendants infringe claim 6 of the ’376 Patent through the structure and operation of the WCDMA base transmission stations (“BTS”) that Defendants have employed and continue to employ. These WCDMA BTS are supplied to Defendants by, among others, Nokia and Ericsson, and include Radio Network Controllers (“RNC”) and Node-Bs.

30. Claim 6 of the ’376 Patent requires “at least one programmable electronic device the programmable electronic device operable to, based on a data signal received from a base station or from a mobile station, perform the steps of.” Defendants’ WCDMA BTS are comprised of processors that manage the inner loop power control and outer loop power control processes for the WCDMA network.

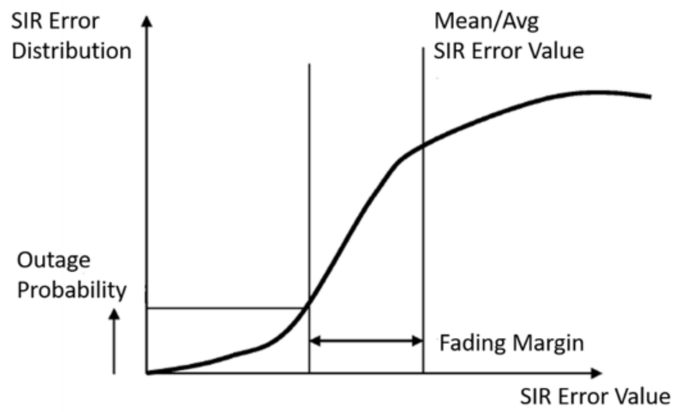
31. Claim 6 of the ’376 Patent further requires “establishing a target block error rate ($BLER_{target}$).” Defendants’ WCDMA BTS, as part of the outer loop power control mechanism

required by the 3GPP UMTS Standard, maintain a configurable parameter for the Block Error Rate ("BLER") Target in the form of a percentage of an acceptable error rate, e.g., 1.

32. Claim 6 of the '376 Patent further requires "calculating an estimate (701) of a desired signal to interference ratio (SIR_{rec})." Defendants' WCDMA BTS, as part of the outer loop power control mechanism required by the 3GPP UMTS Standard, measures the received SIR value (SIR_{Rec}), and compares that value with an established SIR_{Target} value to determine whether a TPC power command should be sent to the UE to have the UE increase or decrease its power output.

33. Claim 6 of the '376 Patent further requires "calculating . . . some fading parameters in a channel (706) which characterize the data signal (107, 108) received." Defendants' WCDMA BTS estimate fading in the uplink channel by comparing the measured SIR_{Rec} values to the temporally commensurate SIR_{Target} values that are used as part of outer loop power control to generate error values that are further collected to determine fading probability.

34. Claim 6 of the '376 Patent further requires "estimating some fading margins (M_1, M_2, . . . , M_N) associated with some outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and with the fading parameters in the channel (706)." Defendants' WCDMA BTS use the collection of error values derived from the comparison of SIR_{Rec} to SIR_{Target} values to determine a distribution of the error values over time. An exemplary distribution function is shown in the figure below:



Applying the distribution function, Defendants' WCDMA BTS use one or more of the percentages of the derivation of the sum of the collected SIR error values from the mean or average error value (outage probability) to calculate a fading margin associated with each percentage.

35. Claim 6 of the '376 Patent also requires "indicating a status of the data blocks (707) based on the checking of a Cyclic Redundancy Code (CRC), and establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (707)." Defendants' WCDMA BTS, as part of the outer loop power control mechanism required by the 3GPP UMTS Standard, adjust the SIR_{Target} value based on block/frame errors indicated by Cyclic Redundancy Check ("CRC") errors.

36. Claim 6 of the '376 Patent lastly requires "establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on . . . the fading margins (M_1, M_2, M_N) and the target block error ($BLER_{target}$) of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (107, 108)." In addition to

modifying the SIR_{Target} value based on the BLER as part of the outer loop power control mechanism, Defendants' WCDMA BTS also adjust the SIR_{Target} value using the one or more fading margin values calculated from the collection of error values generated from the comparison of the SIR_{Rec} and SIR_{Target} values.

COUNT II
(INFRINGEMENT OF THE '865 PATENT)

37. TOT repeats and re-alleges the allegations of Paragraphs 1–25 above as if fully set forth herein.

38. Defendants have infringed and continue to infringe one or more claims of the '865 Patent, including but not limited to Claims 1 and 5, pursuant to 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by using the patented apparatus and methods of the '865 Patent in the United States without authority as part of the implementation of their WCDMA-based wireless networks.

39. Defendants have directly infringed the '865 Patent and are thus liable for infringement of the '865 Patent pursuant to 35 U.S.C. § 271. TOT has suffered, and continues to suffer, damages because of Defendants' infringement of the '865 Patent. TOT is entitled to recover from Defendants the damages adequate to compensate for such infringement, which have yet to be determined.

40. As just one non-limiting example, Defendants infringe claim 1 of the '865 Patent through the operations performed by the WCDMA BTS that Defendants have employed and continue to employ. These WCDMA BTS are supplied to Defendants by, among others, Nokia and Ericsson, and include Radio Network Controllers ("RNC") and Node-Bs.

41. Claim 1 of the '865 Patent requires "estimating a desired signal to interference ratio received (SIR_{rec}) based on a data signal (107.108) received from a base station (102, 103) or mobile

station (104)." Defendants' WCDMA BTS, as part of the outer loop power control mechanism required by the 3GPP UMTS Standard, measures the received SIR value (SIR_{Rec}) and compares that value with an established SIR_{Target} value to determine whether a TPC power command should be sent to the UE to have the UE increase or decrease its power output.

42. Claim 1 of the '865 Patent further requires "setting a desired signal to interference ratio target (SIR_{target}) that is close to a signal to interference ratio required (SIR_{rec}) during the normal mode of the outer loop." Defendants' WCDMA BTS, as part of the outer loop power control mechanism required by the 3GPP UMTS Standard, adjust the SIR_{Target} value based on block/frame errors indicated by Cyclic Redundancy Check ("CRC") errors.

43. Claim 1 of the '865 Patent further requires "detecting a start (402) of the outer loop wind-up." Defendants' WCDMA BTS will detect a "wind-up" condition in the channel based on repeated CRC block errors that result in the frequent repeated increases in the SIR_{Target} value (as part of the outer loop power control) and repeated commands from the BTS to the UE for an increase in power (as part of the inner loop power control). Defendants' WCDMA BTS maintains a history of SIR_{Target} values to determine the instance when the channel entered the "wind-up" condition.

44. Claim 1 of the '865 Patent also requires "setting a specific desired signal to interference ratio target (SIR_{target}) during the outer loop wind-up." Defendants' WCDMA BTS will limit the increases in the SIR_{Target} value based on CRC block errors such that the SIR_{Target} value is capped at a predetermined value during the "wind-up" condition.

45. Claim 1 of the '865 Patent lastly requires "detecting a start (403) of the outer loop unwinding, wherein the desired signal to interference ratio target (SIR_{target}) is modified at the start (403) of the outer loop unwinding, to match it to the outer loop power control in normal mode just

prior to the start of the outer loop wind up." Defendants' WCDMA BTS will detect the end of the "wind-up" condition in the channel based, at least in part, on the cessation of repeated CRC block errors that characterized the "wind-up" condition. Upon the detection of the end of the "wind-up" condition, Defendants' WCDMA BTS will adjust the SIR_{Target} to value consistent with a value of the SIR_{Target} before the "wind-up" condition began.

PRAYER FOR RELIEF

WHEREFORE, TOT respectfully requests that this Court enter judgment in its favor as follows:

a. holding that Defendants have directly infringed literally and/or under the doctrine of equivalents, one or more claims of the Patents-in-Suit;

b. holding that TOT is entitled to pre-suit damages consistent with, *e.g.*, 35 U.S.C. § 287;

c. awarding TOT the damages to which it is entitled under 35 U.S.C. § 284 for Defendants' past infringement, including a reasonable royalty and lost profits;

d. awarding TOT costs and expenses in this action;

e. awarding TOT pre- and post-judgment interest on its damages;

f. enjoining Defendants from further infringement of the Patents-in-Suit; and

g. awarding TOT such other and further relief in law or in equity as this Court deems just and proper.

JURY DEMAND

TOT, under Rule 38 of the Federal Rules of Civil Procedure, requests a trial by jury of any and all issues so triable by right.

Dated: February 1, 2021

Respectfully submitted.

By: /s/ Erick S. Robinson

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EXHIBIT 1

US007496376B2

(12) **United States Patent**
Campo Camacho et al.

(10) **Patent No.: US 7,496,376 B2**
(45) **Date of Patent: Feb. 24, 2009**

(54) **OUTER LOOP POWER CONTROL METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS SYSTEMS**

(75) Inventors: **Alfonso Campo Camacho**, Madrid (ES); **Miguel Blanco Carmona**, Madrid (ES); **Luis Mendo Tomas**, Madrid (ES); **José M Hernando Rabanos**, Madrid (ES); **Alvaro Lopez Medrano**, Madrid (ES)

(73) Assignee: **T.O.P. Optimized Technologies, S.L.** (ES)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 543 days.

(21) Appl. No.: **11/292,715**

(22) Filed: **Dec. 1, 2005**

(65) **Prior Publication Data**

US 2007/0042718 A1 Feb. 22, 2007

(30) **Foreign Application Priority Data**

Aug. 17, 2005 (ES) 200502056

(51) **Int. Cl.**
H04B 7/00 (2006.01)
H04Q 7/20 (2006.01)

(52) **U.S. Cl.** **455/522**; 455/127.1; 455/127.5; 455/114.2; 455/63.1; 370/331; 370/332; 370/335; 370/342

(58) **Field of Classification Search** 455/522, 455/127.5, 63.1, 67.11, 114.2, 135, 126, 455/127.1, 117.2; 370/311, 331, 332, 335, 370/342, 328, 329, 333
See application file for complete search history.

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2005/0215276	A1 *	9/2005	Koo et al.	455/522

* cited by examiner

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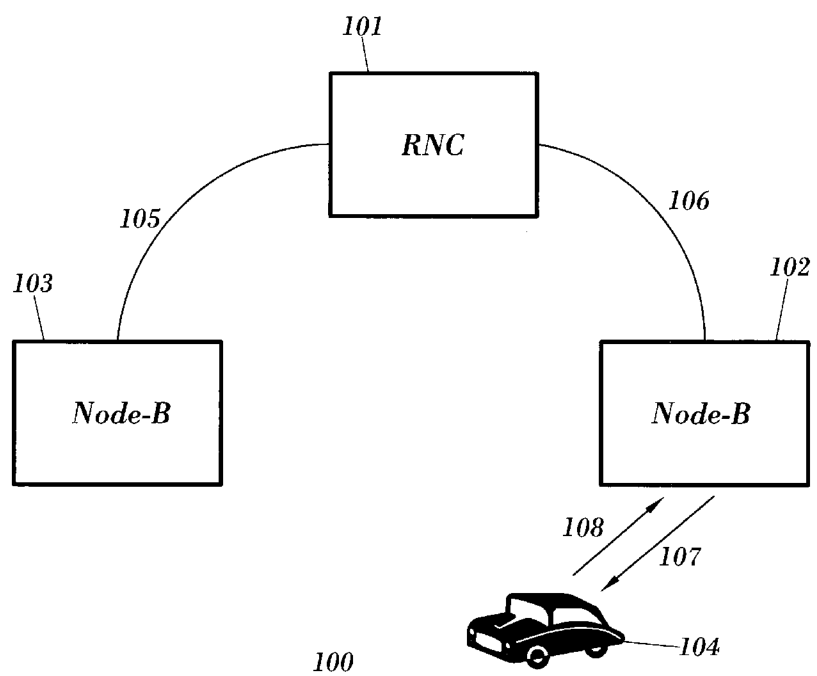
(57) **ABSTRACT**

Outer loop power control (OLPC) method and apparatus for mobile communications systems which allow rapid adjustment of the target desired signal to interference ratio (SIR_{target}) satisfying a target block error rate ($BLER_{target}$). Specifically, the outer loop power control method proposed herein is termed "Outage-Based OLPC" and establishes that the target desired signal to interference ratio (SIR_{target}) is given as the sum of two components: the first component ($SIR_{outage-tgt}$) is calculated by means of a dynamic adjusting function, for example, a neural network which makes a quality criterion based on outage probabilities correspond with one based on the target block error rate ($BLER_{target}$), taking as input the fading margins associated with the different outage probabilities considered; the other component ($SIR_{BLER-tgt}$) is that which acts to correct the possible deviations in the target block error rate ($BLER_{target}$) due to the non-ideal behavior of the previous component ($SIR_{outage-tgt}$).

13 Claims, 8 Drawing Sheets



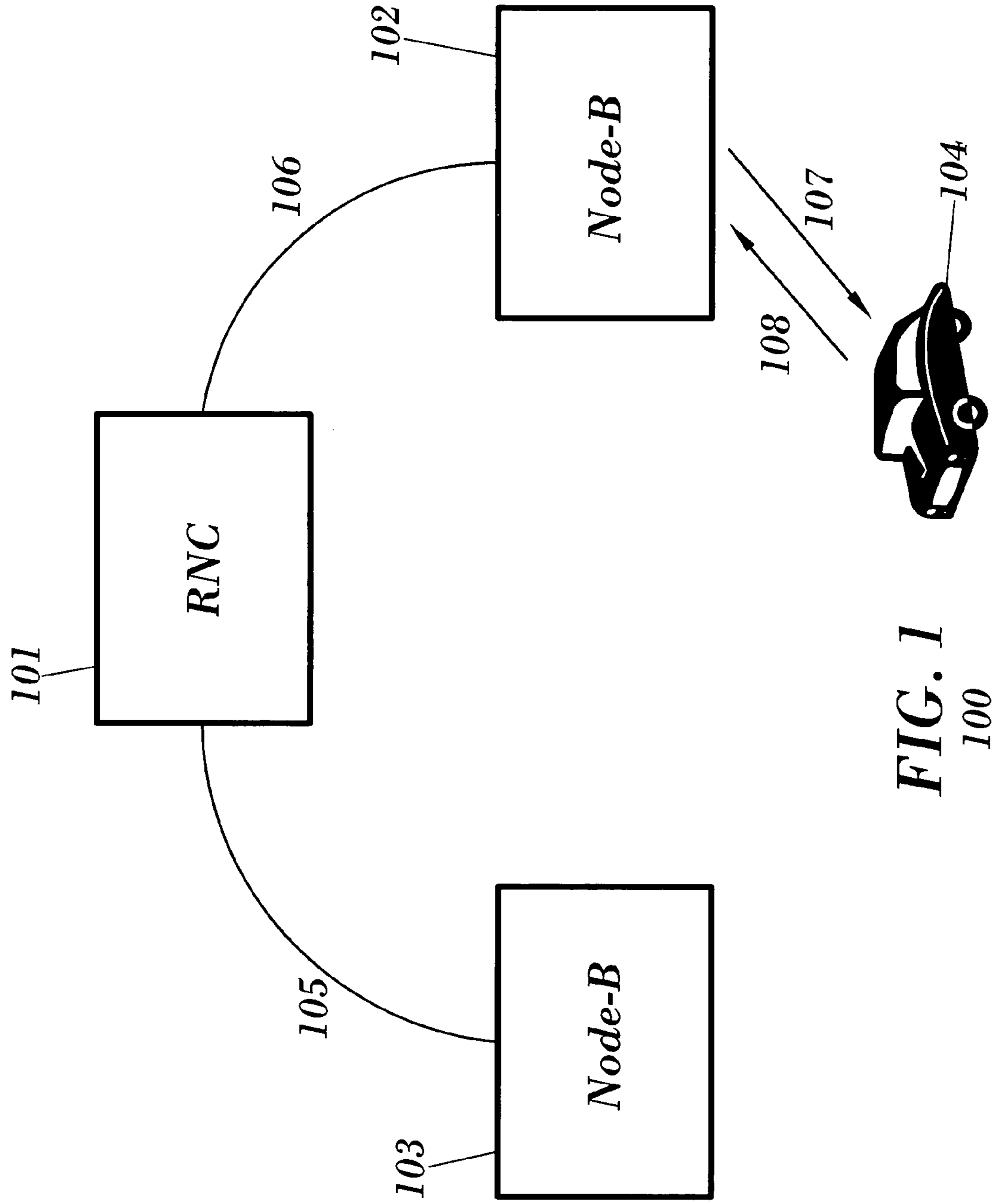


FIG. 1
100

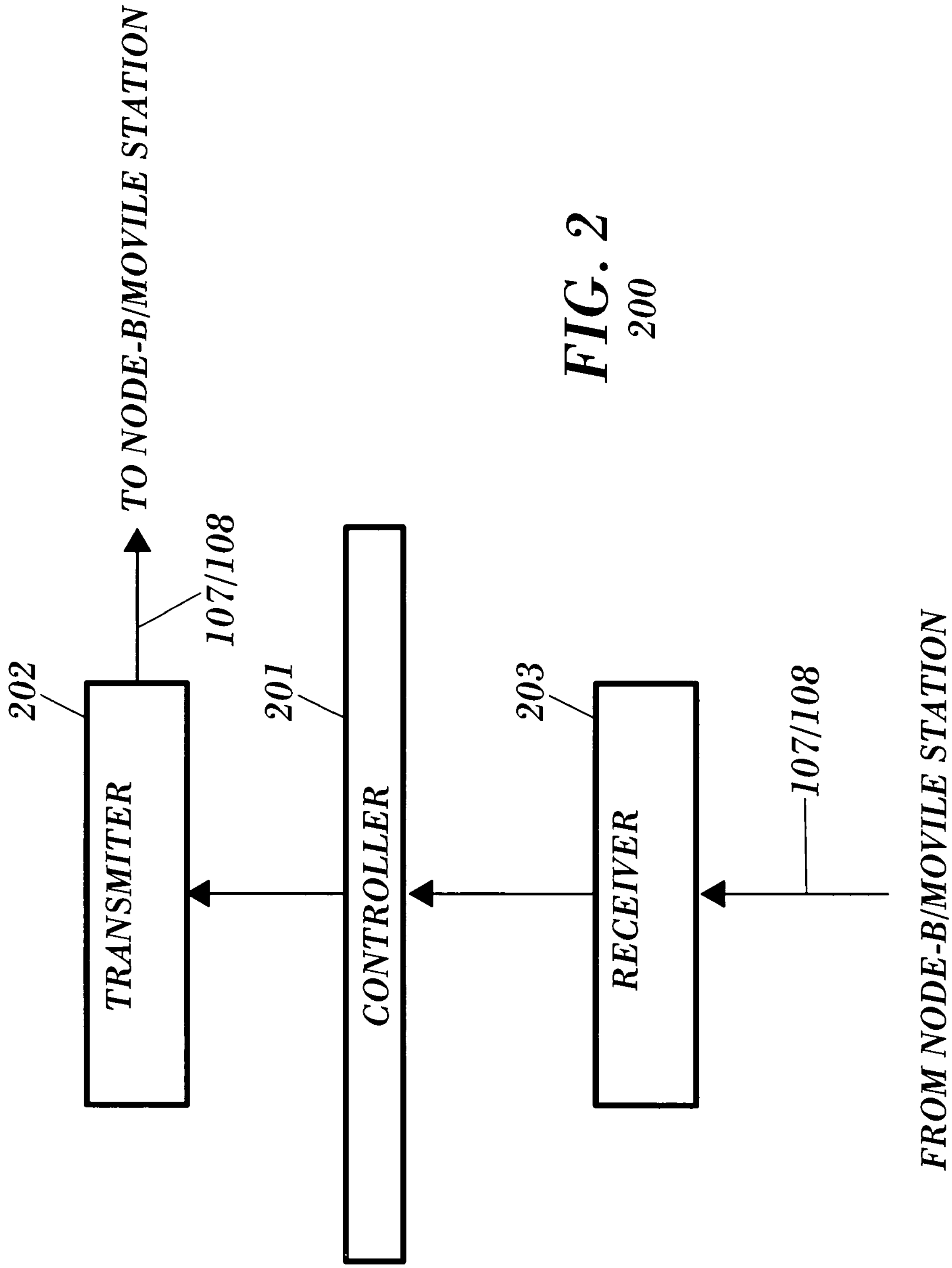

TO NODE-B/MOVILE STATION
107/108
202
TRANSMITTER
201
CONTROLLER
203
RECEIVER
107/108
FROM NODE-B/MOVILE STATION

FIG. 2
200

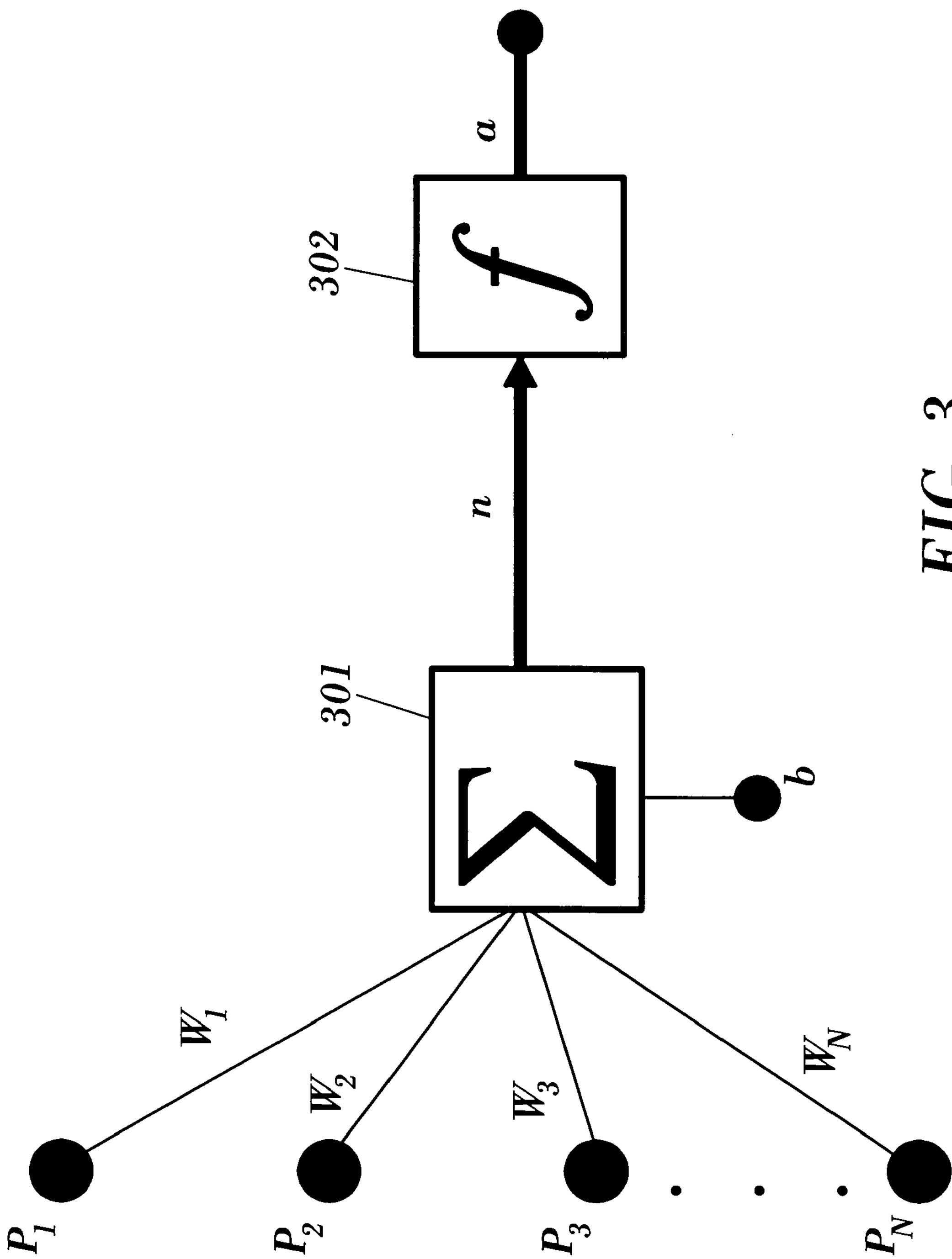
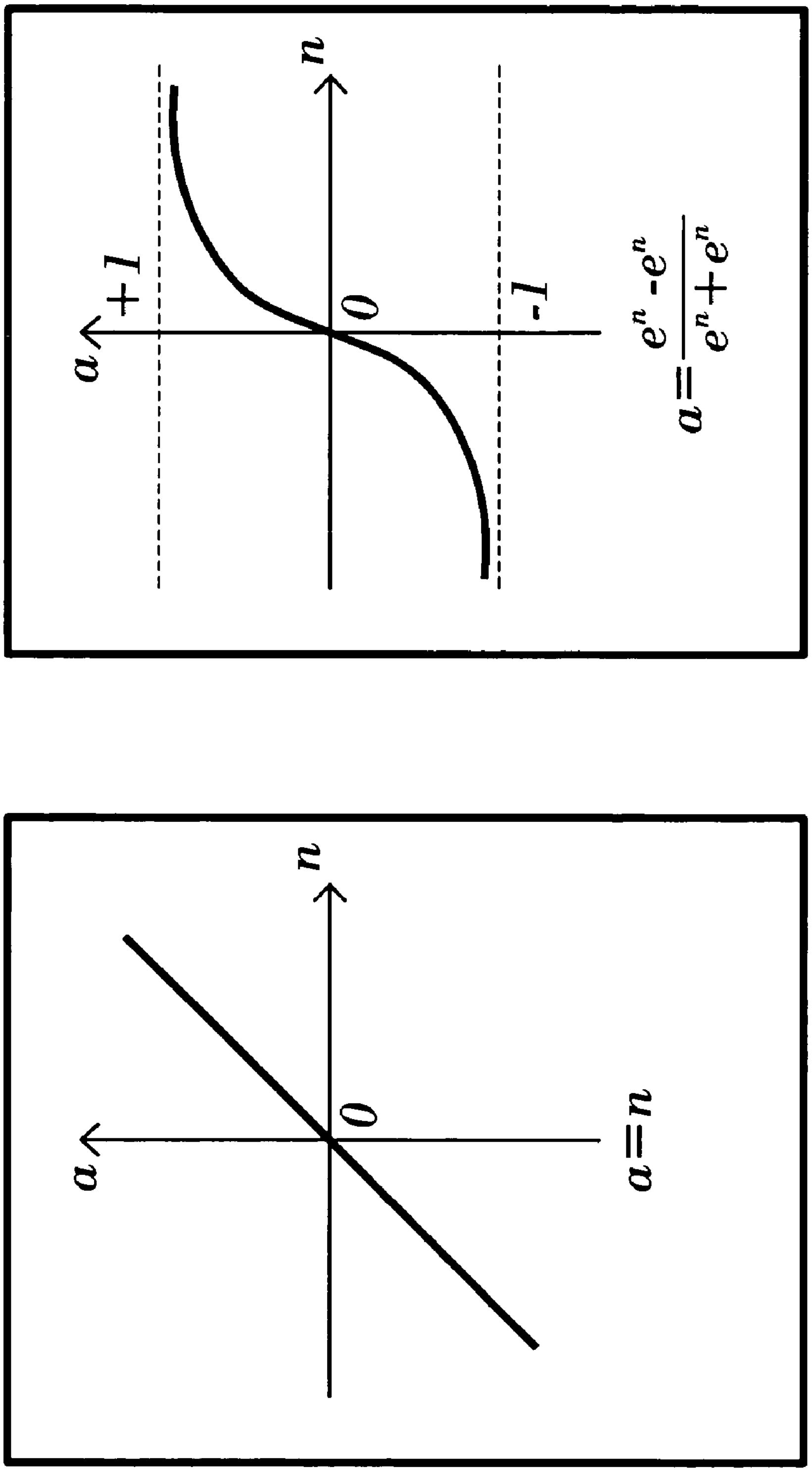


FIG. 3
300



402

401

FIG. 4
400

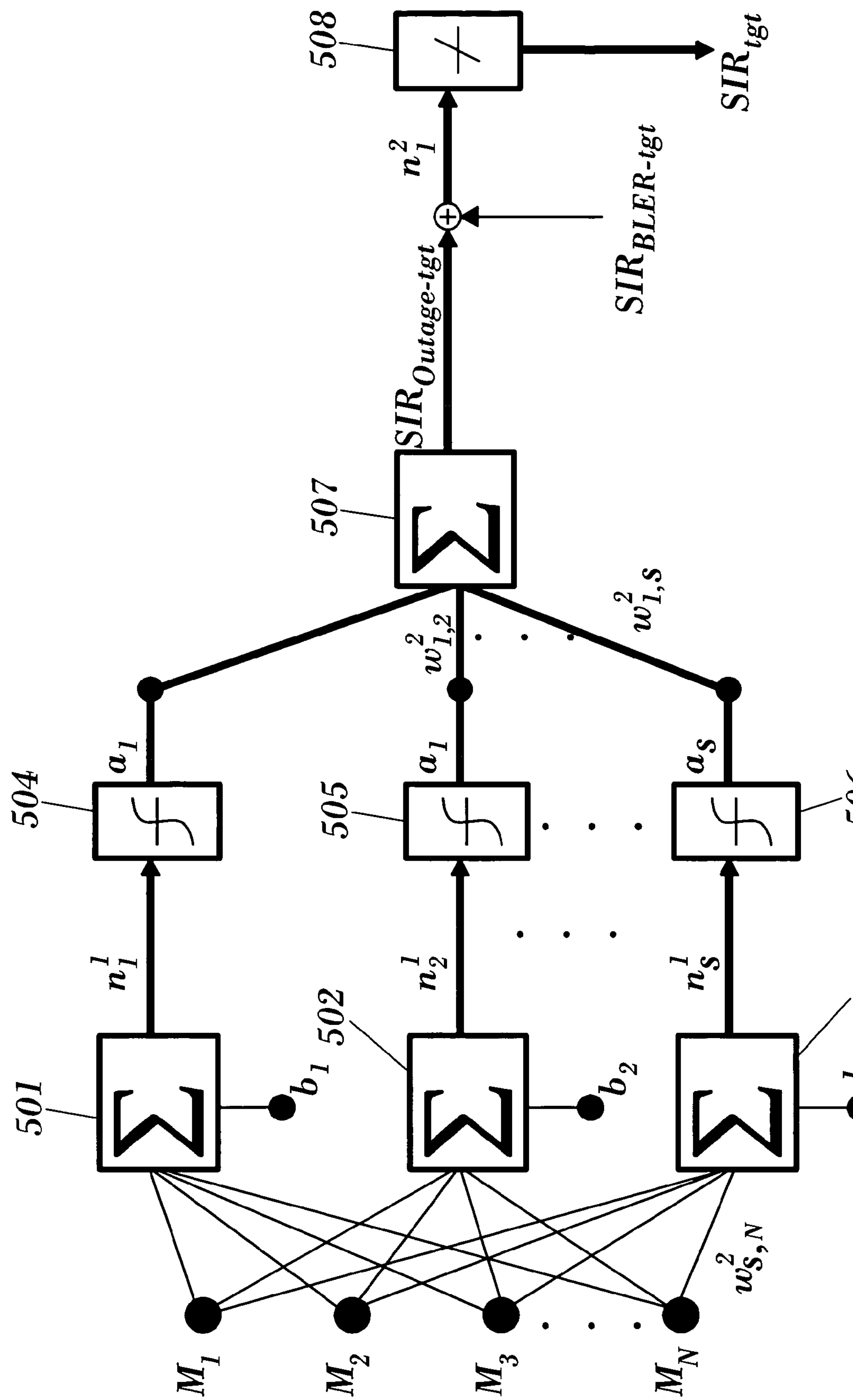

508
SIR_{tgt}
n_1^2
$SIR_{BLER\text{-}tgt}$
$SIR_{Outage\text{-}tgt}$
507
$w_{1,2}^2$
$w_{1,S}^2$
504
505
506
a_1
a_1
a_S
n_1^1
n_2^1
n_S^1
501
502
503
b_1
b_2
b_S
$w_{S,N}^2$
M_1
M_2
M_3
M_N

FIG. 5
500

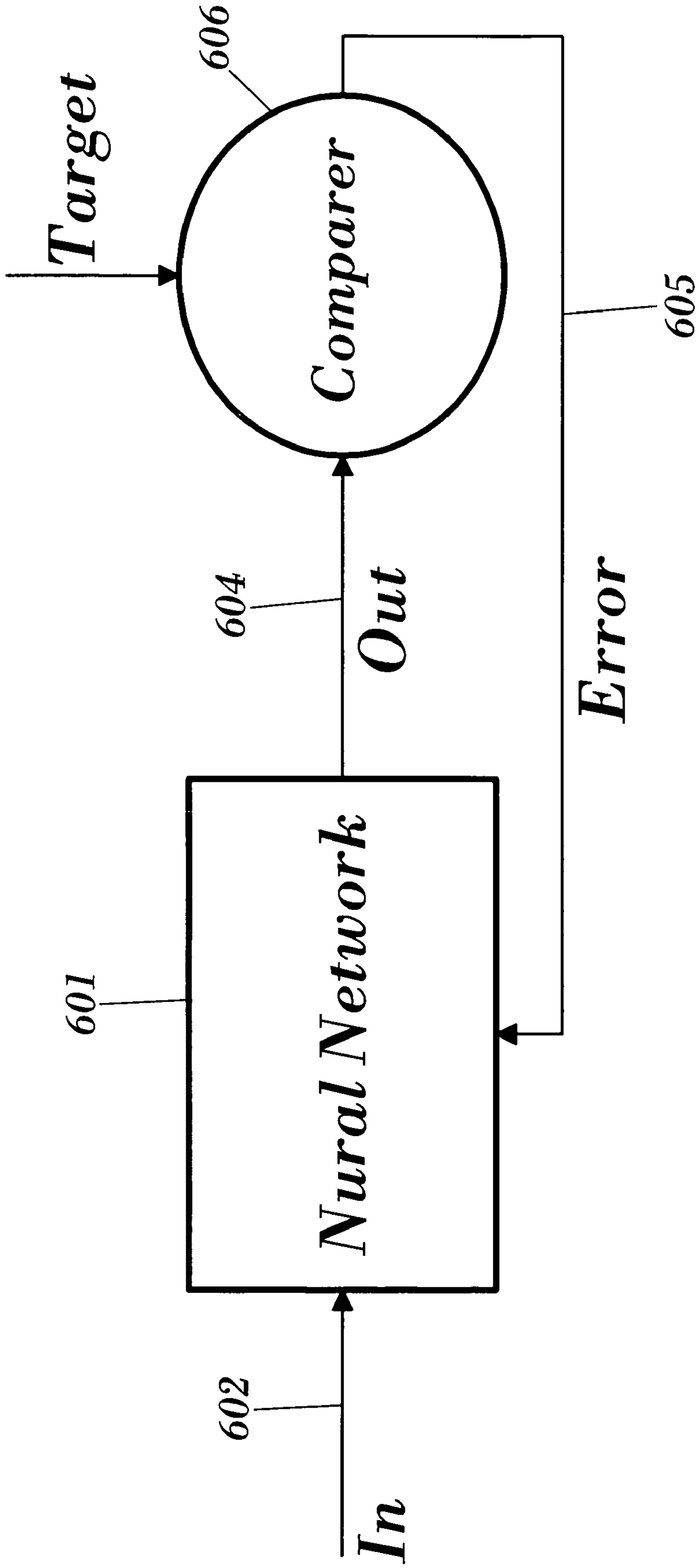
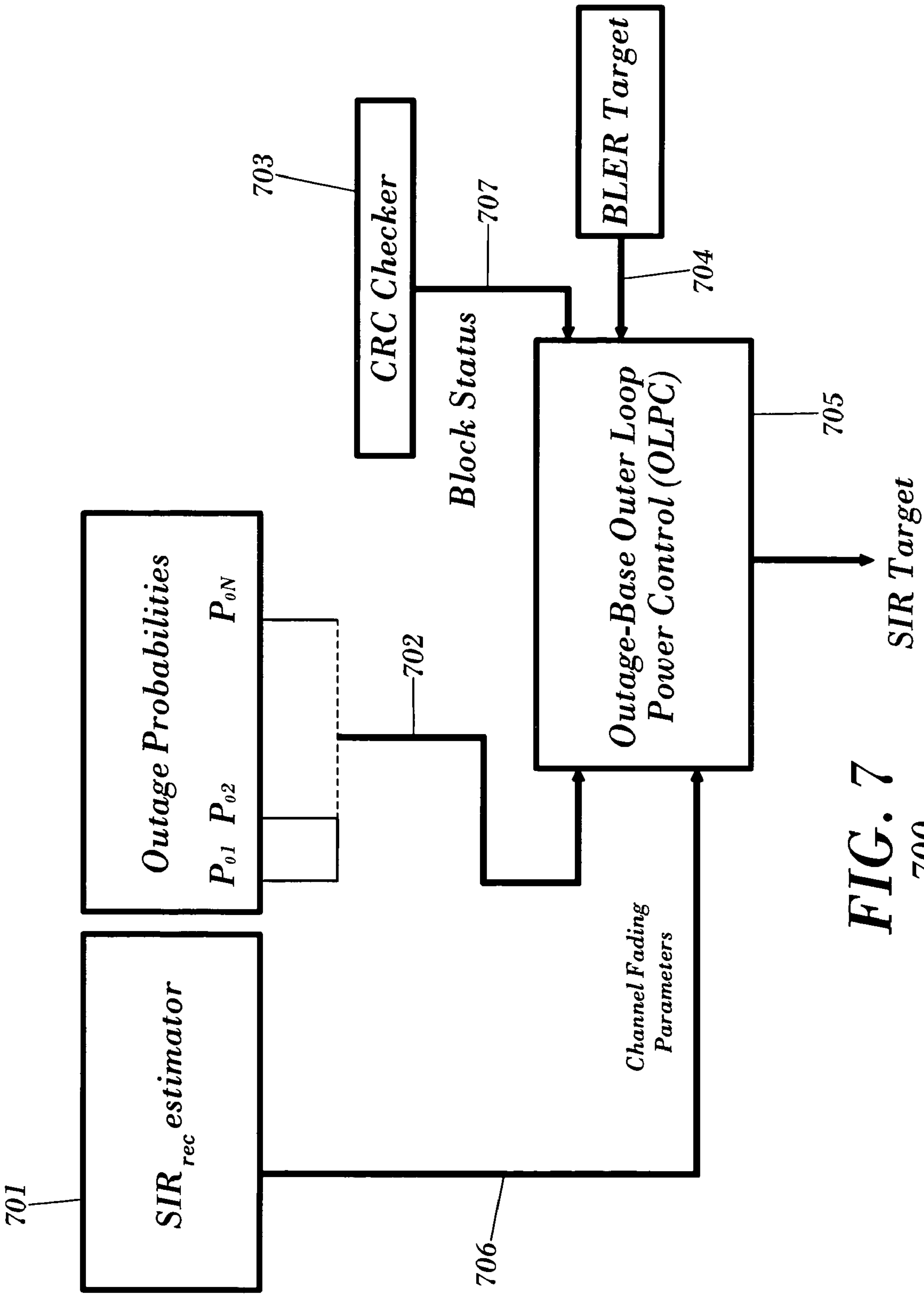

Target
606
Comparer
605
604
Out
Error
601
Nural Network
602
In

FIG. 6
600



703
CRC Checker
707
BLER Target
704
Block Status
Outage-Base Outer Loop Power Control (OLPC)
705
SIR Target
Outage Probabilities
P_{01} P_{02} P_{0N}
702
Channel Fading Parameters
701
SIR_{rec} estimator
706

FIG. 7
700

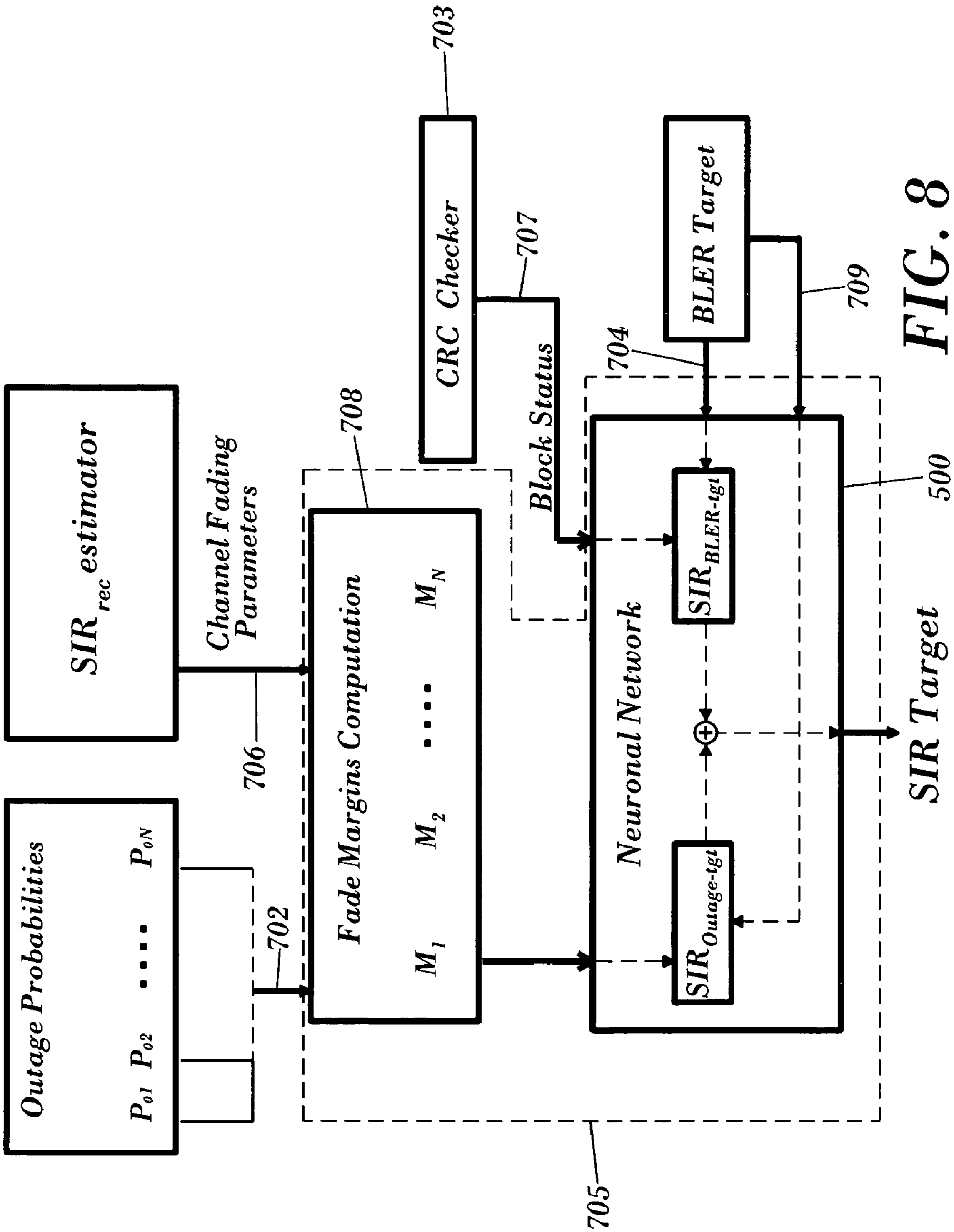

703
CRC Checker
707
Block Status
BLER Target
709
704
500
SIR_{rec} estimator
Channel Fading Parameters
706
708
Fade Margins Computation
M_1 M_2 .... M_N
Neuronal Network
$SIR_{BLER\text{-}tgt}$
$SIR_{Outage\text{-}tgt}$
SIR Target
Outage Probabilities
P_{o1} P_{o2} .... P_{oN}
702
705

FIG. 8

OUTER LOOP POWER CONTROL METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 119 of Spanish Patent Application No. 200502056 filed Aug. 17, 2005, incorporated herein by reference.

OBJECT OF THE INVENTION

The present invention has its application within the telecommunications sector and, especially, in the industrial area engaged in the production of both base stations and mobile terminals in cellular infrastructures for wireless communications systems.

More particularly, the invention described herein, within communications relates to a method and device for the system of outer loop power control in a cellular mobile telephony network.

An object of the invention is to permit power control by means of the outer loop procedure which, supplemented with the method of the invention and which is termed herein "Outage-Based OLPC", adapts to the changing propagation conditions of the communication channel.

It is also an object of the invention to provide a device adapted to be incorporated in the controller of a base station or of a mobile terminal, which carries out the dynamic adjustment of the power level according to the target desired signal to interference ratio established by the Outage-Based OLPC method which is disclosed.

BACKGROUND OF THE INVENTION

In January 1998, the European Telecommunications Standards Institute (ETSI) selected the basic technology for the Universal Mobile Telecommunications System (UMTS) (see ETSI, "The ETSI UMTS Land Radio Access (UTRA) ITU-R RTT Candidate Submission", June 1998). The main radio interface proposed was the Wideband Code Multiple Division Access (WCDMA) protocol, the characteristics of which offer the opportunity to fully satisfy the requirements of third generation (3G) mobile telephony. Due to the high data transmission rate and to the increasingly demanding requirements for quality of service (QoS) in 3G, the development is required of new planning strategies. Among them, that which is probably the greatest object of study is the system of power control, in particular that of the procedure employed to implement the outer loop of said system.

The aforementioned system of power control is described below in general terms, because the functionality of the outer loop, for which this invention proposes a method, is a consequence of other components of the system.

The system of power control in WCMDA-based cellular networks, is necessary since it concerns a technology limited by interference, because all the users share the same frequency spectrum and their codes are not totally orthogonal (see Holma & Toskala: "WCDMA for UMTS, Radio Access for Third Generation Mobile Communications", John Wiley & Sons).

The ultimate goal of the power control system in WCDMA is to attain the required quality of service in a particular connection, downlink from the base station to the mobile terminal or terminal unit, or, uplink from the mobile terminal to the base station, with a minimum level of transmitted power (this aspect is precisely that on which the invention is centred).

The main objectives of the system of power control in WCDMA networks are:

Cancellation of the near-far effect: in the event of all the mobile stations transmitting the same power without taking into account the distance or the fading to the base station, the mobiles nearest the same would signify substantial interference for the most remote terminals.

Protection against deep fading.

Minimization of the interference in the network with the ensuing improvement in capacity.

Enhanced duration of the battery of the mobile stations.

A system of power control for WCMDA is implemented overall by means of three distinct procedures:

By open loop: during the random access process when setting up a connection, the base/mobile station estimates the loss of power in the uplink/downlink connection and in terms thereof adjusts its transmission power.

By closed or inner loop: also termed fast power control (1500 Hz) which consists of the following three steps:

1. The corresponding receiving terminal (the base station or the mobile unit) compares the value of the received desired signal to interference ratio (SIR_{rec}) with the target desired signal to interference ratio (SIR_{target}) which depends on the quality of service required for that specific connection and which is fixed by the outer loop procedure explained below.
2. The same receiving terminal sends power control bits indicating that the transmission power should be increased (if $SIR_{rec}<SIR_{target}$) or decreased (if $SIR_{rec}>SIR_{target}$) in a certain value (usually 1 dB).
3. The transmitting unit (base station or mobile) increases or decreases its power in the previously fixed amount.

By outer loop (OLPC, Outer Loop Power Control): this is much slower than the closed loop (10-100 Hz) and establishes the target desired signal to interference ratio (SIR_{target}) which causes a predetermined quality objective to be maintained. A criterion or a measurement of the quality of a connection is the frame error rate (FER) or equivalently the block error rate (BLER), which is a function of the desired signal to interference ratio (SIR_{rec}). Since the inner loop helps to maintain the desired signal to interference ratio (SIR_{rec}) near the target (SIR_{target}), the block error rate (BLER) is, ultimately, determined by this target value. Thus, to attain a quality of service in a determined fading environment, the target (SIR_{target}) needs to be adjusted to the value appropriate for that environment.

Unfortunately, a target (SIR_{target}) does not exist which can attain the block error rate (BLER) required for all the fading environments in the wireless communication channel. For this reason, the dynamic adjustment of this target desired signal to interference ratio (SIR_{target}) is today an object of study and mechanisms have been described to adjust said ratio conveniently.

The commonly accepted design for outer loop power control (OLPC) is that based on the target block error rate ($BLER_{target}$) and termed "BLER-Based OLPC", which measures this metric and changes the target desired signal to interference ratio (SIR_{target}) in consequence, depending on whether the target block error rate ($BLER_{target}$) is above or below the desired threshold (see Sampath A, Kumar P S & Holtzman J M (1997), "On setting reverse link target SIR in a CDMA system", Proceedings of the IEEE Vehicular Technology Conference, Phoenix, Ariz., pp 929-933.). The drawback

is that, bearing in mind that the technique of measuring the block error rate (BLER) is quite slow, especially for high quality services, the features of these systems are greatly impaired in dynamic environments with fading characteristics changing in very short intervals of time (see Holma H., "WCDMA for UMTS", John Wiley & Sons, Ltd., 2002). The aforementioned slowness for the services that require a low block error rate (BLER) (for example: 0.1%) is due to the "BLER-based OLPC" method being based on counting the errors by means of the Cyclic Redundancy Code (CRC), which implies an excessively high number of data blocks to arrive at a precise estimate of the block error rate (BLER).

The most serious problem is that which arises when a favourable change occurs in the propagation conditions in which event the "BLER-based OLPC" method reacts very slowly, causing the target desired signal to interference ratio (SIR_{target}) fixed by said outer loop power control method to be greater than that necessary for a long period of time, with the consequent increase in interference and, therefore, the loss of system capacity.

Much investigation has been applied aimed at resolving the slow convergence of the power control method which, as has been explained, occurs in the "BLER-Based OLPC". One of the options most employed as a possible solution consists in carrying out modifications to the size of the adjusting steps for the target desired signal to interference ratio (SIR_{target}) which is imposed by the cited BLER-based OLPC method (see again Sampath A, Kumar P S & Holtzman J M (1997), "On setting reverse link target SIR in a CDMA system", Proc. IEEE Vehicular Technology Conference, Phoenix, Ariz., pp 929-933.). However, that option does not overcome the inherent problem with this type of power control method since it also involves a very high number of data blocks for the precise estimation of the block error rate (BLER). Based on this principle of the quality criterion which obeys the target block error rate ($BLER_{target}$), some methods can be cited which have been object of the following patent applications in the United States: US 2004/0137860, US 2004/0157636 and US 2003/0031135.

Another of the most usual alternatives to overcome the problem of the slow convergence of the BLER-Based OLPC method is the consideration of other metrics (the so-called "soft metrics"), among which are: Bit Error Rate (BER), re-encoded Symbol Error Rate (SER), a metric of re-encoded power, number of decoding iterations, modified metric of Yamamoto and the Euclidean Distance (ED) (see Rege Kiran, "On Link Quality Estimation for 3G Wireless Communication Networks", in the Proceedings of the IEEE VTS Fall VTC2000. 52nd Vehicular Technology Conference). These metrics have the advantage over the block error rate (BLER) that they can be estimated with much greater speed.

Since the purpose of the OLPC is that of meeting a target of constant block error rate ($BLER_{target}$) and for a moderate change in the block length due to the propagation conditions of the channel, a practically fixed ratio is established between the block error rate (BLER) and the aforementioned "soft metric" parameters, with which it is possible to find the target block error rate ($BLER_{target}$) based on an estimate of any one of said metrics. By way of example, mention can be made of some designs of methods based on these metrics which have been object of the following patents: U.S. Pat. No. 6,434,124 and U.S. Pat. No. 6,763,244.

Nevertheless, the drawback of the outer loop power control based on such metrics arises when a change in the propagation conditions of the channel substantially affects the block length. In this situation, the correlation between the block error rate (BLER) and the metrics considered as "soft metrics" are no longer fixed and therefore a constant block error rate ($BLER_{target}$) is not obtained (see Avidor, Dan, "Estimating the Block Error Rate at the Output of the Frame Selector in the UMTS System", in Proceedings of the Wireless Networks and Emerging Technologies (WNET 2002), Wireless and Optical Communications (WOC 2002), July 2002, Banff, Alberta, Canada.).

On the other hand, Jonas Blom, Fredrik Gunnarson and Fedrik Gustafsson in their patent application U.S. Pat. No. 6,449,462, establish a method to control the target desired signal to interference ratio (SIR_{target}) also based on measuring the block error rate (BLER), but together with the calculation of some determined representative parameters of the different conditions of the radiofrequency channel and of the statistical distribution of the interfering signals. The method is based on the determination of a quality function defined as the errored frame probability conditioned by the aforementioned parameters. Although this strategy implies gains in capacity of the order of 30%, the process for obtaining said quality function imposes a delay which impairs the benefits of this type of model. Separately, in the article by the same authors in which the invention is described in more technical detail: "Estimation and Outer Loop Power Control in Cellular Radio Systems" presented at ACM Wireless Networks, it is stated that the system can be degraded due to fading in the radiofrequency channel.

The applicant of the present patent, Álvaro López Medrano in Spanish patent application ES 200202947 (see also the articles by Álvaro López-Medrano: "Optimal SIR target determination for Outer loop Control in the W-CDMA System", Proceedings of the IEEE Vehicular Technology Conference (VTC) Fall 2003, 6-9 Oct. 2003, Orlando (USA) and "Optimal SIR target determination for Outer loop Control in the W-CDMA System: Inverse SIR Cumulative Distribution Function computation throughout the Newton-Raphson Method", Proceedings of the 12th IST Summit on Mobile and Wireless Communications (Volume II), pp. 732-736, 15-18 Jun., 2003, Aveiro, Portugal) proposes an outer loop of the power control system in 3G systems based on a quality criterion different to that of the target block error rate ($BLER_{target}$). This quality criterion on which the method described in ES 200202947 is based, is the outage probability (P_{outage}), with which the aforesaid inherent low speed of convergence of the BLER-based OPLC method is avoided.

As is explained in ES 200202947, the outage probability (P_{outage}) constitutes another habitually applied quality parameter in cellular infrastructures, which is established previously, during the planning phase of the communications network, in terms of the class of service covered by the communication link, the characteristics of the cells and, inside each cell, the characteristics of the service area. Based on this outage probability (P_{outage}), it is proposed in the aforementioned patent application to determine the fading margin ($M_{(Sii)}$ (dB)) corresponding to the desired signal to interference ratio and, therefore, the target desired signal to interference ratio (SIR_{target}) for a quality of service criterion given by the outage probability (P_{outage}) and some characteristic statistical moments of the radiofrequency channel under consideration.

The explanation given in the preceding paragraph is expressible as a mathematical problem first proposed by S. Kandukuri and S. Boyd (in IEEE Transactions on Wireless Communications, vol. 1, no. 1, pp. 46-55, January 2002) and known as "Optimal power control in interference-limited fading wireless channels with outage-probability specifications", which was resolved by Álvaro López Medrano in his previously cited patent application, by applying the iterative

method of Newton-Raphson (see H. R. Schwarz, J. Waldvogel "Numerical Analysis", John Wiley & Sons) to outer loop power control.

In brief, the outer loop power control method proposed by López Medrano in the previous patent application ES 200202947 is based on the quality criterion of outage probability (P_{outage}), but a final commitment of an outer loop must be to maintain constant a target block error rate ($BLER_{target}$) which corresponds to a determined service (see the specification documents of the Third Generation Standard 3GPP: TS 25.101, "UE radio transmission and reception (FDD), section 8.8.1" and the TS 25.104, "Base station (BS) radio transmission and reception (FDD), section 8"). Consequently, it is not possible to maintain a constant outage probability (P_{outage}) for all propagation conditions, as the actual block error rate (BLER) does not remain constant. This is because there is no fixed ratio between the outage probability (P_{outage}) and the block error rate (BLER), but instead it depends on the propagation conditions in the radio link that are taking place at that moment.

As the fading margin, which is the outcome of the outer loop power control method disclosed in ES 200202947, is a function of such an outage probability (P_{outage}) among other variables, the dynamic adaptation thereof implies changes in said margin. And in conclusion, the target desired signal to interference ratio (SIR_{target}) ought to be adjustable contemplating the changes in the fading margin, to adapt the outer loop power level to whatever propagation conditions, the power to be transmitted being minimum.

DESCRIPTION OF THE INVENTION

The present invention serves to resolve, among others, the aforesaid problem, in all of the different aspects explained in the background hereto.

The method and device of outer loop power control for mobile communications systems which are disclosed, specially conceived for third generation (3G) technologies based on any of the standardized protocols of Code Division Multiple Access (CDMA), guarantee on one hand a quality of service (QoS) criterion in terms of a pre-established block error rate (BLER) and, on the other, they are able to adapt quickly to changing conditions in the radiofrequency channel following a new quality criterion, in addition to the previous one (the BLER criterion), which is based on the outage probability.

Therefore one aspect of the invention is an outer loop power control method for wireless communications systems which, based on a received data signal, coming from a base station or mobile unit, comprises the following phases:

i. establishing a target block error rate ($BLER_{target}$)

ii. estimating the ratio of desired signal to interference (SIR_{rec}) and of some parameters which characterize the fading in the channel (**706**) suffered by the received signal,

iii. estimating fading margins, by means of the Newton-Raphson method, based on the fading parameters in the channel and on outage probabilities,

iv. determining the state of the data blocks, based on checking the Cyclic Redundancy Code (CRC),

V. establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said state of the data blocks, the target block error rate ($BLER_{target}$) and the estimated fading margins associated with the outage probabilities considered.

The target desired signal to interference ratio (SIR_{target}) which the proposed method of power control establishes, herein termed "Outage-Based OLPC", is calculated as the sum of two components, which are termed $SIR_{outage\text{-}tgt}$ and $SIR_{BLER\text{-}tgt}$, through a dynamic adjusting function which carries out a mapping between the quality criterion based on the target block error rate ($BLER_{target}$) and another quality criterion, this one based on the outage probabilities.

Thus, the required quality of service (QoS) is satisfied, with the minimum power level necessary, the power adapting quickly and dynamically to the propagation conditions of the data signal, for which reason, since it is an interference-limited technology, it signifies the capacity of the system is also optimised.

The dynamic adjustment function with which the target desired signal to interference ratio (SIR_{target}) is established as the sum of the two components mentioned: SIR_{tgt}= $SIR_{outage\text{-}tgt}$+$SIR_{BLER\text{-}tgt}$, consists preferentially of a neural network.

Within the ambit of this description, a neural network is understood to be a tool to implement a parameterizable generic function, to which weighting and offsets are applied which represent the parameters of the function, which can be adjusted, which is known as training a neural network, to obtain a certain desired behaviour.

As is well known, the neurons of a neural network are organized in layers, a layer of neurons being defined as that group of neurons which share some same inputs. The outputs of one neuron layer constitute the inputs of the following layer.

Within the neural networks, the multiplayer type is more versatile than a network with a single layer (see Martin T. Hagan, Howard B. Demuth, Mark H. Beale, "Neural Network Design", PWS Pub. Co., 1st edition, 1995). For example, a two-layer network, a first sigmoidal layer and a second linear layer, can be trained to approximate the majority of functions arbitrarily well. For the case in point, this is the structure implemented for the neural network of the method which establishes the target desired signal to interference ratio (SIR_{target}) of the outer loop for power control.

The neural network disclosed has a first layer with a number of neurons which depends on the number of considered outage probabilities and a second layer which has a single neuron by having a single output: the value of the target desired signal to interference ratio (SIR_{target}). The input parameters are the fading margins calculated for the different outage probabilities. To incorporate the corrective term which corresponds to the quality criterion based on the target block error rate ($BLER_{target}$), the offset of the neuron of the output layer is made to correspond with the ($SIR_{BLER\text{-}target}$) component of the final target desired signal to interference ratio (SIR_{target}).

The other component ($SIR_{outage\text{-}target}$) is generated by means of the neural network described and adapts to the changing propagation conditions, for which reason it must have a fast variation behaviour.

To be able to achieve this fast variation, such ($SIR_{outage\text{-}target}$) component has to be tied to parameters of the physical signal on which the fading takes place, like for example the outage probability. Nevertheless, the final quality target is that based on the target block error rate ($BLER_{target}$), whereby this parameterizable function is necessary which performs the mapping of the physical signal parameters, the outage probabilities, to quality parameters corresponding to the block error rate (BLER). To this end, the neural network takes as input the fading margins associated with different outage probabilities. Said margins can be calculated, as is described in the patent application ES 200202947, by inverting the distribution function of the

received desired signal to interference ratio (SIR_{rec}) by means of the known Newton-Raphson method.

However, the adaptation provided by the first component ($SIR_{outage-tgt}$) of the target desired signal to interference ratio (SIR_{target}) established for outer loop power control is not always ideal and not all channel variations are taken into account. Therefore, the outer loop is not by itself capable of guaranteeing the pre-established criterion of target block error rate ($BLER_{target}$). It is for this reason that, to cover non-ideal behaviour, the second component ($SIR_{BLER-target}$) is included in the final target desired signal to interference ratio (SIR_{target}), which serves to assure that the quality defined by the target block error rate ($BLER_{target}$) is indeed maintained in the service.

Ideally, this last component ($SIR_{BLER-target}$) would remain constant, because the variation therein signifies that the other component ($SIR_{outage-target}$) of the target desired signal to interference ratio (SIR_{target}) does not have the appropriate value and the reason is that the variations in the channel have not been properly taken into account. In practice, for this reason, the component ($SIR_{BLER-target}$) will have small variations in order to guarantee the target block error rate ($BLER_{target}$), but it will not be imperative that it respond instantaneously to changes in the channel.

Both in the ideal or simulated real environment in a laboratory, and in the environment where the method is implemented within the ambit of a wireless communications system existing in practice, the neural network of the method undergoes training whenever variations arise in the component ($SIR_{BLER-target}$). The neural network mentioned is defined by the parameters which weight the different margins and some certain offset values. For the calculation thereof, simulations are carried out of multiple propagation environments wherein the valid values of the target desired signal to interference ratio (SIR_{target}) are obtained for each environment considered. Those values are obtained by considering as quality target the target block error rate ($BLER_{target}$) and, with them, proceeding to optimise the parameters of the neural network which minimize the error of the target desired signal to interference ratio (SIR_{target}) for all propagation conditions. Thus, it is possible to relate the two quality criteria considered: that which is based on the target block error rate ($BLER_{target}$) and that of the outage probability (P_{outage}).

The parameters of the neural network are obtained according to simulation data, when the method is being applied within a system working in a real environment, being adjusted in a dynamic fashion so that the quality criterion satisfied is that given by the target block error rate ($BLER_{target}$) of the service and in addition the power consumption is minimized in each communication. Addressing both commitments, the input data taken are the development in time of the received desired signal to interference ratio (SIR_{rec}) which is measured, as well as the mean block error rate (BLER) obtained in the communication. With these data, the parameters of the neural network will be adjusted to the environment of each of the cells in the mobile network.

As a result, the method object of the invention allows the use of power control mechanisms for the outer loop based on a quality criterion different to the known criterion of the target block error rate ($BLER_{target}$), a criterion being proposed based on the Outage Probability (P_{outage}), without impairment of the quality of service (QoS) based on said target block error rate ($BLER_{target}$) but improving the features of the outer loop, for the reasons that are explained in the aforementioned patent application ES 200202947.

Another aspect of the invention relates to an outer loop power control apparatus for wireless communications systems, which comprises at least one programmable electronic device which operates according to the previously described method. The programmable electronic device can be a general-purpose processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC) and a programmable array (FPGA) or any combination of the foregoing. The general-purpose processor can be preferably a microprocessor or other possible alternatives: a conventional processor, a micro-controller or any state machine in general. Furthermore, the programmable electronic device can consist of a combination of multiple microprocessors, a microprocessor and one or more DSP devices, or any other configuration in which the performance of the different phases is distributed, in series or in parallel, comprised in the method which has been described.

Optionally, the outer loop power control apparatus for wireless communications systems which is disclosed, can comprise a radiofrequency receiver capable of receiving the data signal coming from a base station or mobile unit. Additionally, a radiofrequency transmitter can also be incorporated in this device, capable of sending the information on power control to the pertinent base station or mobile unit. Thus, such a device of outer loop power control can be incorporated in a controller of wireless communications networks, or, in the user terminal equipment or mobile unit of the wireless communications systems.

Some last aspects of the invention include a Radio Network Controller: (RNC, which includes the logic for processing the calls) and a mobile station (UE: user equipment or remote terminal), each device comprising the device of outer loop power control for wireless communications systems so described.

The invention is applicable to any wireless communications system which supports one or more standards of the CDMA protocol, standards such as WCDMA, IS-95, CDMA2000, the HDR specification, etc.

DESCRIPTION OF THE DRAWINGS

To complete the description that is being made and with the object of assisting in a better understanding of the characteristics of the invention, in accordance with a preferred example of practical embodiment thereof, accompanying said description as an integral part thereof, is a set of drawings wherein, by way of illustration and not restrictively, the following has been represented:

FIG. **1**.—It shows a part of a mobile communications system, as known in the state of the art, which includes the elements of a cellular infrastructure, mobile terminal of the user, base station and remote controller of the network, related with the object of the invention.

FIG. **2**.—It shows a block diagram, according to the state of the art, of the part of a base station or of a mobile unit which is related with the invention.

FIG. **3**.—It shows a schematic representation of a neuron, the basic element upon which and on the interconnections thereof a neural network is defined, according to a definition known in the state of the art.

FIG. **4**.—It shows graphs of possible functions which are habitually used as transfer function in a neural network.

FIG. **5**.—It shows a schematic representation of the two-layer neural network, with which it is possible to implement the outer loop power control method according to the object of the invention and according to a preferred embodiment.

FIG. **6**.—It shows a generic model of training for a neural network, as defined in the state of the art of neural networks.

FIG. **7**.—It shows a block diagram with the input and output parameters of the outer loop power control method for mobile communications systems object of the invention, to which the name "Outage-Based OLPC" has been given.

FIG. **8**.—It shows a block diagram of the outer loop power control method for mobile communications systems object of the invention, illustrating the breaking down of the target desired signal to interference ratio (SIR_{target}) into the two components ($SIR_{outage\text{-}tgt}$, $SIR_{BLER\text{-}tgt}$) which are added, together with the appropriate input parameters.

PREFERRED EMBODIMENT OF THE INVENTION

In FIG. **1**, a part (**100**) is shown of a WCDMA mobile communications system. Apart from the invention, the elements shown in the figure are well known and they are not described in detail. One element of interest is the user terminal unit or mobile station (**104**) which is represented by means of the vehicle icon; also the WCDMA mobile communications system comprises several base stations (**102**, **103**), or B-nodes in the UMTS network which contain processors, memories, interface cards and embedded software programs. This part of the system includes a radio network controller (**101**) or RNC, which, among other functions, provides the call processing. The two base stations (**102**, **103**) and the mobile station (**104**) are representative of end points of the wireless interface. Each base station (**102**, **103**) is associated with an RNC (**101**) over some land lines (**105**, **106**). Hereinafter, it is assumed that the mobile station (**104**) is in communication with the base station (**102**), by means of the data signal (**107**) of the downlink connection and of the data signal (**108**) of the uplink connection.

FIG. **2** shows the part (**200**) of both stations, base station (**102**) and mobile station (**104**), which includes the principles on which this invention is based. The known aspects of the elements which appear in the aforementioned figure are not treated, since a radiofrequency transmitter (**202**) and a receiver (**203**) are described in detail in the state of the art. Both the base station (**102**) and the mobile station (**104**) contain a controller (**201**), a transmitter (**202**) and a receiver (**203**). Thus, in the case of the base station (**102**), the received signal corresponds to the uplink connection (**108**) and in the case of the mobile unit (**104**), the signal received is that of the downlink connection (**107**), both reach the controller (**201**) through the receiver (**203**). The power control apparatus object of the invention is incorporated in the controller (**201**) and sends a command through the transmitter (**202**) which indicates to the station receiving at that moment that it should increase or decrease its power, depending on the result of the outer loop power control method which is described next, the object of which is to establish the target desired signal to interference ratio (SIR_{target}) which acts as threshold in the closed loop for the power control.

The method of the invention, which is termed herein "Outage-Based OLPC" insofar as it constitutes an outer loop power control (OLPC) which guarantees a quality criterion in terms of a target block error rate ($BLER_{target}$) and is also able to adapt the power quickly to the conditions of the radiofrequency channel, considering another quality criterion based on the outage probability, is developed according to some steps which take place in the controller (**201**) and which are detailed below.

The present invention proposes that the target desired signal to interference ratio (SIR_{target}) which is provided for the outer loop is given as the sum of two components: a first component ($SIR_{outage\text{-}tgt}$) and a second component ($SIR_{BLER\text{-}tgt}$), such that:

$$SIR_{tgt}=SIR_{outage\text{-}tgt}+SIR_{BLER\text{-}tgt}$$

The first component ($SIR_{outage\text{-}tgt}$) is a function of some fading margins ($M_1, M_2, \ldots, M_N$), calculated previously by means of the Newton-Raphson method or another applicable and associated with some outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) considered. Therefore, this component ($SIR_{outage\text{-}tgt}$) has a fast variational behaviour with permits it to adapt to changing propagation conditions, although said behaviour is not always ideal, that is, not all channel variations are taken into account by the aforementioned ($SIR_{outage\text{-}tgt}$) and in itself it does not guarantee the pre-established criterion of target block error rate ($BLER_{target}$), if it were not because it is supplemented with the other component ($SIR_{BLER\text{-}tgt}$).

The second component ($SIR_{BLER\text{-}tgt}$) covers the non-ideal behaviours of the channel, assuring that the target block error rate ($BLER_{target}$) is indeed maintained for the service. This component ($SIR_{BLER\text{-}tgt}$) would remain constant in an ideal environment, but in practice, it will present small variations, it not being imperative that it respond instantaneously to changes in the channel. For this reason, it is necessary to maintain in this component ($SIR_{BLER\text{-}tgt}$) the characteristic step procedure of the known "BLER-based OLPC" method (see again Sampath A, Kumar P S & Holtzman J M (1997), "On setting reverse link target SIR in a CDMA system", Proc. IEEE Vehicular Technology Conference, Phoenix, Ariz., pp 929-933.), which actually has the characteristics of a slow response but which is capable of assuring the specified target block error rate (BLERtarget) exactly.

Returning now to the first component ($SIR_{outage\text{-}tgt}$), which is determined, as has already been commented, by a function of the fading margins ($M_1, M_2, \ldots, M_N$) associated with the different outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) considered, the fact that not only one outage probability and therefore only one associated fading margin are considered, is because it is not possible to maintain the outage probability constant for all propagation conditions, nor would the block error rate (BLER) be constant and, in consequence, the target of the outer loop would not be maintained. The previous discrepancy between outage probability and block error rate (BLER) is because there is no constant ratio between the two criteria, but rather it depends precisely on the radio conditions present at the time.

Hereunder, several forms are proposed for finding the function which based on the fading margins ($M_1, M_2, \ldots, M_N$) gives the first component ($SIR_{outage\text{-}tgt}$) as a result, so that the "Outage-Based OLPC" method satisfies the quality criterion imposed by the target block error rate ($BLER_{target}$), complying with a minimum power consumption in the transmission.

One of the simplest alternative embodiments that can be proposed is a linear combination of the fading margins ($M_1, M_2, \ldots, M_N$), whereby the first component ($SIR_{outage\text{-}tgt}$) is a summation of said fading margins ($M_1, M_2, \ldots, M_N$) weighted or multiplied by some appropriate fading margin constants ($K_1, K_2, \ldots, K_N$), resulting in the target desired signal to interference ratio (SIR_{target}):

$$SIR_{tgt}=SIR_{BLER\text{-}tgt}+k_1{\cdot}M_1+k_2{\cdot}M_2+\ldots+k_N{\cdot}M_N \tag{1}$$

A particular case is the method which is described in the patent application ES 200202947 mentioned as a precedent; indeed, if in the previous equation all the constants are cancelled except one and a single fading margin is taken:

$k_1=1$

$k_i=0\,\forall i\neq 1$

the result is:

$$SIR_{target}=SIR_{outage}+k_1{\cdot}M_1$$

To generalize the problem to more cases which contemplate all the propagation conditions, involving non-linear functions, use will be made of neural networks as the tool for the possibility of defining such not necessarily linear functions and which adapt to the propagation conditions in real communications environments.

The neural network model which will be used to illustrate the principle of the invention is the following: FIG. **3** shows a neuron (**300**), the basic element based on which and on its interconnections a neural network is defined. A generic neuron (**300**) has N inputs ($p_1, p_2, \ldots, p_N$) which when weighted by some factors ($w_1, w_2, \ldots, w_N$), are introduced into an adder (**301**). Also, an offset (b) is applied to the adder, which is added to the weighted inputs of the neuron (**300**), in such a way that the value at the output (n) of the adder (**301**) is:

$$n = b + \sum_{i=1}^{N} w_i \cdot p_i$$

This value (n) is the input argument of a transfer function (**302**) which allows, for example, non-linear behaviours to be introduced and the result of which is the final output (a) of the neuron (**300**). In FIG. **4**, some functions are represented graphically which are habitually used as transfer function (**302**): the first graphic (**401**) corresponds to a linear transfer function and the graphic (**402**) to a sigmoidal function of hyperbolic tangent type.

A preferred implementation of the function which does the mapping between a quality criterion based on the outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and the quality criterion based on the target block error rate ($BLER_{target}$), which characterizes the method of the invention is the neural network (**500**) shown in FIG. **5**, with a possible two-layer structure. This neural network (**500**) has N inputs which correspond with the estimated fading margins ($M_1, M_2, \ldots, M_N$), which as has been said, are associated with the outage probabilities ($p_{o1}, \ldots, p_{o2}, \ldots, p_{oN}$) and with some fading parameters in the channel (**706**) which characterize the received data signal (**107**, **108**). Said fading parameters in the channel (**706**) can be statistical moments such as those contemplated in the aforementioned patent application ES 200202947: the standard deviation corresponding to log-normal fading (σ_N), the Rice factor (K) of the desired signal and the standard deviation (σ_I) corresponding to the distribution which describes the variations of the interference signals.

The neural network (**500**) comprises at least one input layer and a single output layer, although in a possible embodiment like that shown in FIG. **5**, it is also simplified to a single input layer.

The input layer of the neural network (**500**) or first layer of neurons, which will be denoted by the suffix **1** in the parameters associated therewith, is constituted by S neurons. Each of the neurons has a first stage consisting of an adder (**501**, **502**, **503**) with N inputs corresponding to the N inputs of the neural network (**500**) weighted by the factors ($w_{i,j}$) where i denotes the index of each input and j the index of each neuron. In addition, each adder (**501**, **502**, **503**) has an offset (b_j) which is added to the weighted inputs of the neuron, in such a way that the value (n_j) at the output of its adder (**501**, **502**, **503**) is:

$$n_j = b_j + \sum_{i=1}^{N} w_{i,j}^1 \cdot M_i$$

Each value (n_j) is taken to a transfer function (**504**, **505**, **506**) which produces the respective outputs (a_j) and which allows, for example, the introduction of non-linear behaviours. Said outputs (a_j) of the first layer of neurons will be the inputs of the following layer of neurons.

The model can be extended to an arbitrary number of layers of neurons although for simplicity only two layers are shown.

The behaviour and the blocks which conform the second layer of neurons in FIG. **5** are conceptually the same as in the first layer, although with some particularities arising from this being the output layer of the neural network (**500**). This has an influence basically in three aspects. In the first place, this last layer comprises a single neuron which provides the only output of the neural network (**500**), which is in fact the target desired signal to interference ratio (SIRtarget) for the outer loop. So that the output layer can generate the required values, the output range of the transfer function (**508**) has to be chosen accordingly. In the proposed example a linear function has been chosen with infinite output range. Lastly, as has already been commented, the offset applied in the adder (**507**) of this output neuron corresponds with the corrective term based on the target block error rate ($BLER_{target}$), namely, the second component ($SIR_{BLER\text{-}tgt}$) of the final target desired signal to interference ratio (SIR_{target}) which is therefore:

$$\sum_{j=1}^{S} w_{1,j}^2 + SIR_{BLER\text{-}tgt} = SIR_{outage\text{-}tgt} + SIR_{BLER\text{-}tgt} = SIR_{tgt}$$

It is necessary to keep in mind that a characteristic of the first component ($SIR_{outage\text{-}tgt}$) of this target desired signal to interference ratio (SIR_{target}) is that, in contrast to the fading margins ($M_1, M_2, \ldots, M_N$) which are used for the calculation thereof, it can be negative.

In FIG. **6** the training model of a generic neural network (**601**) is described. To be able to carry out the adjustment of the internal parameters, weightings and offsets of the various neurons which constitute the neural network (**500**, **601**), it is necessary to have an input data set (**602**) and the targets (**603**) which the network has to attain for said inputs. There are well known algorithms which permit the network to be trained minimizing the error (**605**) between the output values (**604**) and the targets (**603**) which a comparator (**606**) provides.

In the neural network (**500**) proposed, it will be necessary to have, in known propagation environments, the margins ($M_1, M_2, \ldots, M_N$) for the outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) selected, which will have to be introduced as input data and the optimum target desired signal to interference ratio (SIR_{target}) for each environment, to which the output of the neural network (**500**) will have to be adjusted. By means of error backpropagation algorithms, the weightings (w_i) and the offsets (b_i) are adjusted of all the layers to minimize the error at the output with different propagation conditions.

It is easy to check that the linear combination solution outlined initially is included in this other one as a particular case. In fact, even the procedure of adjusting coefficients is very similar, endeavouring to reduce, in the case of the linear combination, the error at the output, for example, by a least squares procedure.

The data necessary for training the neural network (**500**), can be obtained either by means of simulation or from measurements in a controlled environment with different propagation conditions. The optimum value of the target desired signal to interference ratio (SIR_{target}) to which the output of the neural network (**500**) has to be adjusted is obtained by

considering a determined target block error rate ($BLER_{target}$) as quality target. On this basis the neural network (**500**) allows a mapping to be established between the quality criteria based respectively on said target block error rate ($BLER_{target}$) and on the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}). In addition, it is of interest to include the greatest variety possible of propagation conditions for taking data, the purpose being to minimize the global error made in the greatest number of possible environments.

Another possibility posited is that the outer loop power control method of the invention operating in a real system can adjust the parameters of its outer loop to adapt them to the environments where the users are located that are communicating. To this end, the variations measured in the second component ($SIR_{BLER\text{-}tgt}$) of the target desired signal to interference ratio (SIR_{target}) give information on the errors which the neural network (**500**) is making, because if it were perfect, the aforementioned component ($SIR_{BLER\text{-}tgt}$) should remain constant in any condition. In fact, it is possible to retrain the neural network (**500**) on the basis of the variations in this component ($SIR_{BLER\text{-}tgt}$).

The input data which are used in this Outage-Based Outer Loop Power Control (OLPC) method, which this invention discloses, are defined hereinafter using as reference the blocks of the diagram (**700**) of FIG. **7**:

Firstly, an estimation (**701**) is made of the received desired signal to interference ratio (SIR_{rec}) by means of the corresponding hardware architecture (see Sáez Ruiz, Juan Carlos: "A Hardware Architecture for Estimating the Ratio of Signal to Interference in WCDMA Systems", Department of Electroscience, Digital ASIC University of Luna). Within this estimate (**701**), some fading parameters are included in the channel (**706**) which are considered opportune for characterizing the received signal (**107**, **108**). For example, in the aforementioned patent application ES 200202947, the fading parameters in the channel (**706**) considered are: the standard deviation corresponding to the log-normal fading (σ_N) and the Rice factor (K) of the desired signal, as well as the standard deviation (σ_I) corresponding to the distribution which describes the variations of the interfering signals.

The fading margins (M_1, M_2, . . . , M_N) associated with the previous fading parameters in the channel (**706**) are also a function of the corresponding outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) which are considered and, therefore, these outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) constitute another of the inputs (**702**) necessary for the Outage-Based Outer Loop Power Control (OLPC) method object of the invention.

Continuing with the blocks of FIG. **7**, the decoded data of each frame involved in the communication pass to a checker of the CRC (**703**), which determines or indicates if the frame has been decoded correctly or, on the contrary, it contains errors, by checking the bits of the Cyclic Redundancy Code (CRC) added at the end of the data frame. For each frame received and decoded, the checker of the CRC (**703**) provides a status of the data blocks (**707**) which consists of a frame indicating whether the data frame is adequately decoded or, because it is not so, it has been erased. Notice that this is the known operating principle of the earlier BLER-based Outer Loop Power Control (OLPC) method, in which the target desired signal to interference ratio (SIR_{target}) is varied for the outer loop in correspondence with the result which said checker of the CRC (**703**) provides.

The method object of this invention, herein named as "Outage-Based Outer Loop Power Control (OLPC)" takes place in the block (**705**) and which processes all the aforementioned inputs (**702**, **706**, **707**), including the introduction (**704**) of the target block error rate ($BLER_{target}$), in the manner explained in the following paragraphs.

In FIG. **8** the steps are specified in more detail which take place in the block (**705**) of FIG. **7**, that is, a preferred embodiment is shown of the operation of the Outage-Based Outer Loop Power Control (OLPC) method of the invention.

The computation (**708**) or the estimation of the fading margins (M_1, M_2, . . . , M_N) corresponding to the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) which are considered as the input parameters (**702**) thereof, as well as corresponding to the fading parameters in the channel (**706**) given by the estimator (**701**) of the received desired signal to interference ratio (SIR_{rec}), can be made based on the method proposed in the aforementioned patent application ES 200202947. The aforementioned fading margins (M_1, M_2, . . . , M_N) constitute one of the inputs (**710**) of the neural network (**500**) and are used, together with the target block error rate ($BLER_{target}$), introduced by the input (**709**), to obtain the first component ($SOR_{outage\text{-}tgt}$) of the target desired signal to interference ratio (SIR_{target}). Moreover, with the reintroduction (**704**) of the target block error rate ($BLER_{target}$) and of the state of the data blocks (**707**) produced by the checker of CRC (**703**), the second component ($SIR_{BLER\text{-}tgt}$) is obtained. Finally, both components are added and the desired target desired signal to interference ratio (SIR_{target}) is obtained for the outer loop power control.

The foregoing design has been used to describe the principles of the invention, nevertheless other alternatives, although not detailed herein but which incorporate the same spirit and end, are possible. For example, although the invention has been illustrated here by means of discrete functional blocks executable in the controller (**201**) of a wireless communications network, the functions of any one of these blocks can be carried out using one or more conveniently programmed processors.

In like fashion, the invention is applicable for standards other than WCDMA, as well as for the power control of any signal received both by the base stations and by the user terminal units or mobile stations.

The terms in which this specification has been worded are always to be taken in the broadest sense and not restrictively.

What is claimed is:

1. Outer loop power control method for wireless communications systems which based on a data signal (**107**, **108**) received, coming from a base station (**102**, **103**) or from a mobile station (**104**), comprises the following phases:

establishing a target block error rate ($BLER_{target}$),

calculating an estimate (**701**) of a desired signal to interference ratio (SIR_{rec}) and of some fading parameters in a channel (**706**) which characterize the data signal (**107**, **108**) received,

estimating some fading margins (M_1, M_2, . . . , M_N) associated with some outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and with the fading parameters in the channel (**706**), indicating a status of the data blocks (**707**) based on the checking of a Cyclic Redundancy Code (CRC), and

establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (**707**), the fading margins (M_1, M_2, . . . , M_N) and the target block error ($BLER_{target}$) of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (**107**, **108**).

2. Outer loop power control method for wireless communications systems, according to claim **1**, wherein the adjusting function is implemented by means of a neural network (**500**) which comprises at least one input layer in which the fading margins ($M_1, M_2, \ldots, M_N$) are introduced and an output layer which, having been previously trained for the input fading margins ($M_1, M_2, \ldots, M_N$) together with the status of the data blocks (**707**) and the target block error ($BLER_{target}$) of the outer loop, establishes the target desired signal to interference ratio (SIR_{target}) for said outer loop.

3. Outer loop power control method for wireless communications systems, according to claim **2**, wherein the input layer of the neural network (**500**) generates a component ($SIR_{outage\text{-}tgt}$) of the target desired signal to interference ratio (SIR_{target}) which is adapted to the propagation conditions of the data signal (**107**, **108**).

4. Outer loop power control method for wireless communications systems, according to claim **3**, wherein the output layer of the neural network (**500**) adds to the component ($SIR_{outage\text{-}tgt}$) another component ($SIR_{BLER\text{-}tgt}$) obtained from the status of the data blocks (**407**) and the target block error ($BLER_{target}$) of the outer loop, by means of the outer loop power control method which applies the quality criterion based on the target block error rate ($BLER_{target}$).

5. Outer loop power control method for wireless communications systems, according to claim **4**, wherein the neural network (**500**) is trained whenever variations are present in the component ($SIR_{BLER\text{-}tgt}$).

6. An outer loop power control apparatus for wireless communications systems, comprising at least one programmable electronic device the programmable electronic device operable to, based on a data signal received from a base station or from a mobile station, perform the steps of:

establishing a target block error rate ($BLER_{target}$),

calculating an estimate (**701**) of a desired signal to interference ratio (SIR_{rec}) and of some fading parameters in a channel (**706**) which characterize the data signal (**107**, **108**) received,

estimating some fading margins ($M_1, M_2, \ldots, M_N$) associated with some outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and with the fading parameters in the channel (**706**),

indicating a status of the data blocks (**707**) based on the checking of a Cyclic Redundancy Code (CRC), and

establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (**707**), the fading margins (M_1, M_2, M_N) and the target block error ($BLER_{target}$) of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (**107**, **108**).

7. The outer loop power control apparatus for wireless communications systems, according to claim **6**, wherein the programmable electronic device is selected among a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC) and a programmable array (FPGA) or any combination of the foregoing.

8. The outer loop power control apparatus for wireless communications systems, according to claim **6**, further comprising: a radiofrequency receiver (**203**) capable of receiving the data signal (**107**, **108**) coming from the base station (**102**, **103**) or from the mobile station (**104**) of the wireless communications system.

9. The outer loop power control apparatus for wireless communications systems, according to claim **6**, further comprising a radiofrequency transmitter (**202**) capable of sending the power control information to the base station (**102**, **103**) or to the mobile station (**104**) of the wireless communications system.

10. The outer loop power control apparatus in a wireless communications system, according to claim **7**, wherein the outer loop power control apparatus is incorporated in a wireless communications network controller.

11. The outer loop power control apparatus in a wireless communications system, according to claim **7**, wherein the outer loop power control apparatus is incorporated in a mobile station for wireless communications systems.

12. A radio network controller for wireless communications systems, comprising an outer loop power control apparatus, the outer loop power control apparatus comprising:

at least one programmable electronic device, the programmable electronic device operable to, based on a data signal received from a base station or from a mobile station, perform the steps of:

establishing a target block error rate ($BLER_{target}$),

calculating an estimate (**701**) of a desired signal to interference ratio (SIR_{rec}) and of some fading parameters in a channel (**706**) which characterize the data signal (**107**, **108**) received,

estimating some fading margins ($M_1, M_2, \ldots, M_N$) associated with some outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and with the fading parameters in the channel (**706**),

indicating a status of the data blocks (**707**) based on the checking of a Cyclic Redundancy Code (CRC), and

establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (**707**), the fading margins ($M_1, M_2, \ldots, M_N$) and the target block error ($BLER_{target}$) of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (**107**, **108**); and

wherein the programmable electronic device is selected among a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC) and a programmable array (FPGA) or any combination of the foregoing.

13. A mobile station for wireless communications systems, comprising an outer loop power control apparatus the apparatus comprising:

at least one programmable electronic device, the programmable electronic device operable to, based on a data signal received from a base station or from a mobile station, perform the steps of:

establishing a target block error rate ($BLER_{target}$),

calculating an estimate (**701**) of a desired signal to interference ratio (SIR_{rec}) and of some fading parameters in a channel (**706**) which characterize the data signal (**107**, **108**) received,

estimating some fading margins ($M_1, M_2, \ldots, M_N$) associated with some outage probabilities ($p_{o1}, p_{o2}, \ldots, p_{oN}$) and with the fading parameters in the channel (**706**),

indicating a status of the data blocks (**707**) based on the checking of a Cyclic Redundancy Code (CRC), and

establishing a target desired signal to interference ratio (SIR_{target}) for the outer loop, based on said status of the data blocks (**707**), the fading margins ($M_1, M_2, \ldots, M_N$) and the target block error ($BLER_{target}$)

of the outer loop, by means of a dynamic adjusting function which performs a mapping between a quality criterion based on the outage probabilities (p_{o1}, p_{o2}, . . . , p_{oN}) and the quality criterion based on the target block error rate ($BLER_{target}$), so that the power is adapted to the propagation conditions of the data signal (**107**, **108**); and

wherein the programmable electronic device is selected among a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC) and a programmable array (FPGA) or any combination of the foregoing.

* * * * *

EXHIBIT 2

US007532865B2

(12) **United States Patent**
Campo Camacho et al.

(10) **Patent No.: US 7,532,865 B2**
(45) **Date of Patent: May 12, 2009**

(54) **OUTER LOOP POWER CONTROL METHOD AND DEVICE FOR WIRELESS COMMUNICATIONS SYSTEMS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 516 days.

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H04B 1/00 (2006.01)
H04B 7/00 (2006.01)

(52) **U.S. Cl.** **455/69**; 455/522; 455/68; 455/70; 370/318; 370/320

(58) **Field of Classification Search** 455/522, 455/126, 127.1, 114.2, 226.3, 296, 13.4, 455/69, 11.1, 68, 70; 370/318, 320
See application file for complete search history.

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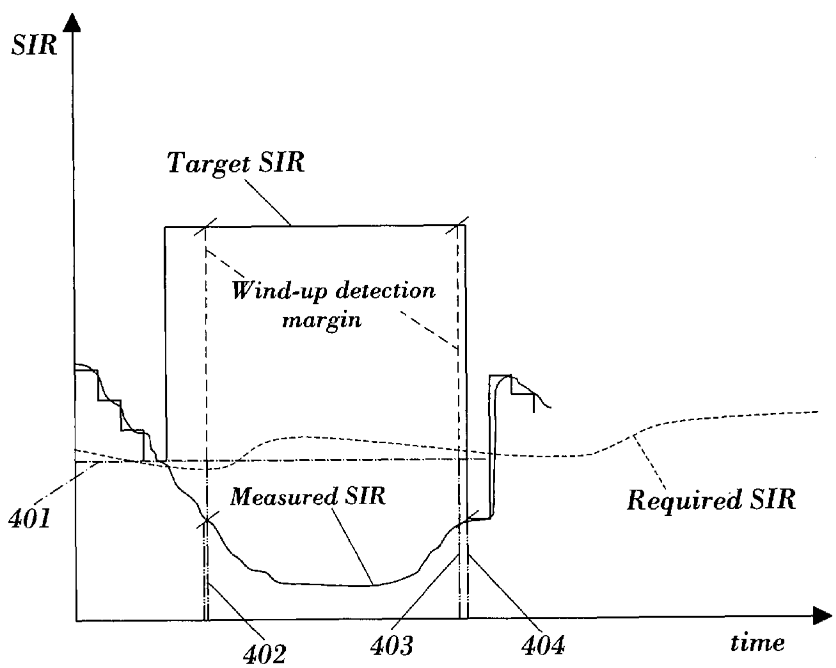
(57) **ABSTRACT**

The method and device proposed for wireless communications systems based on WCDMA technology modifies the desired signal to interference ratio target (SIR_{target}) when it detects the exit from the wind-up condition in the mobile communication, that is, when the unwinding process has started, in order to match it to the outer loop power control in normal mode, setting for this desired signal to interference ratio target (SIR_{target}) a value that is as close as possible to that which it had just before the moment of the start of the wind-up so that immediate afterwards it can continue with the correct variation determined by the power control in the normal mode of the outer loop. Thus, the unwinding time is shortened and the interference in the mobile communication system is reduced, while its capacity and the quality of its wireless connections are increased.

12 Claims, 4 Drawing Sheets



400

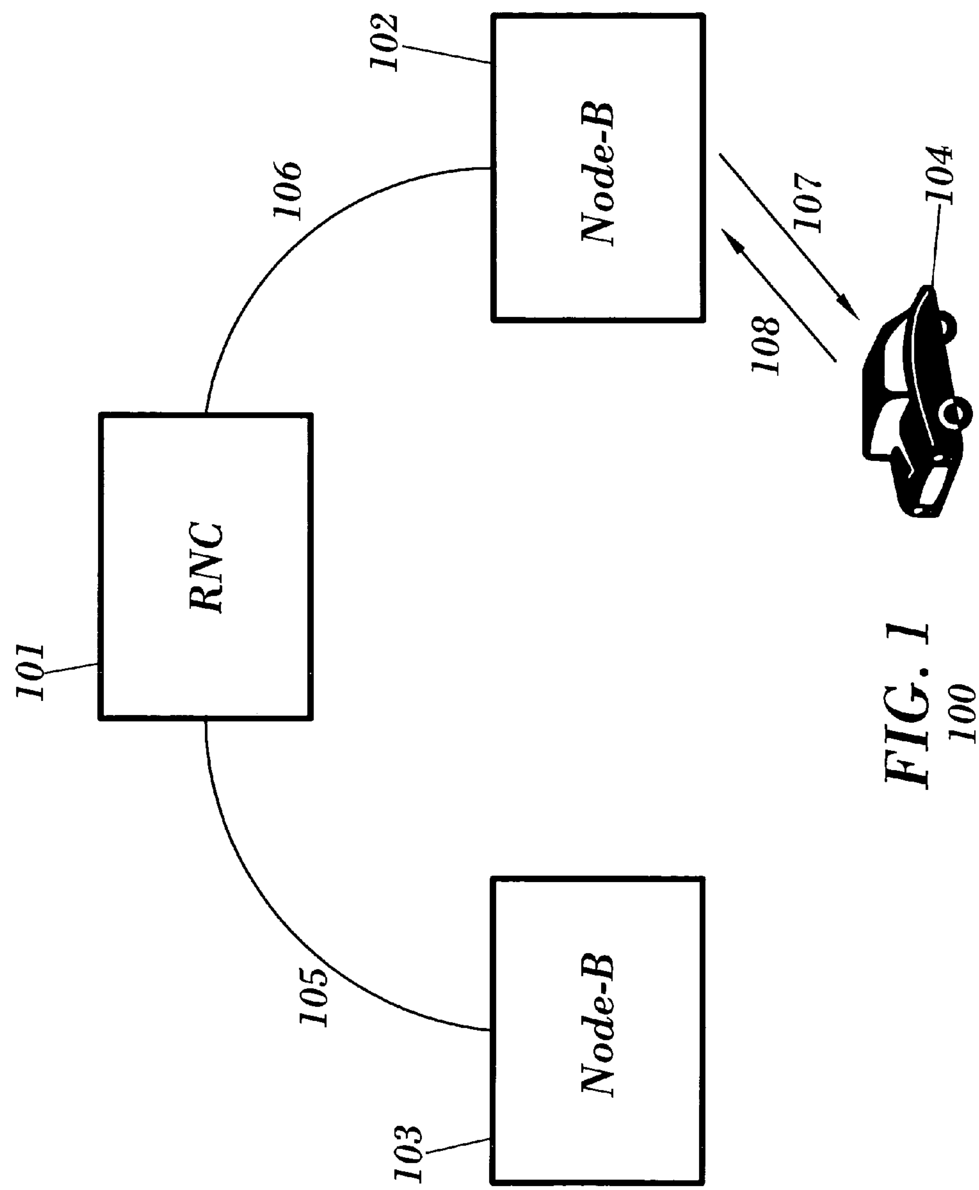


FIG. 1
100

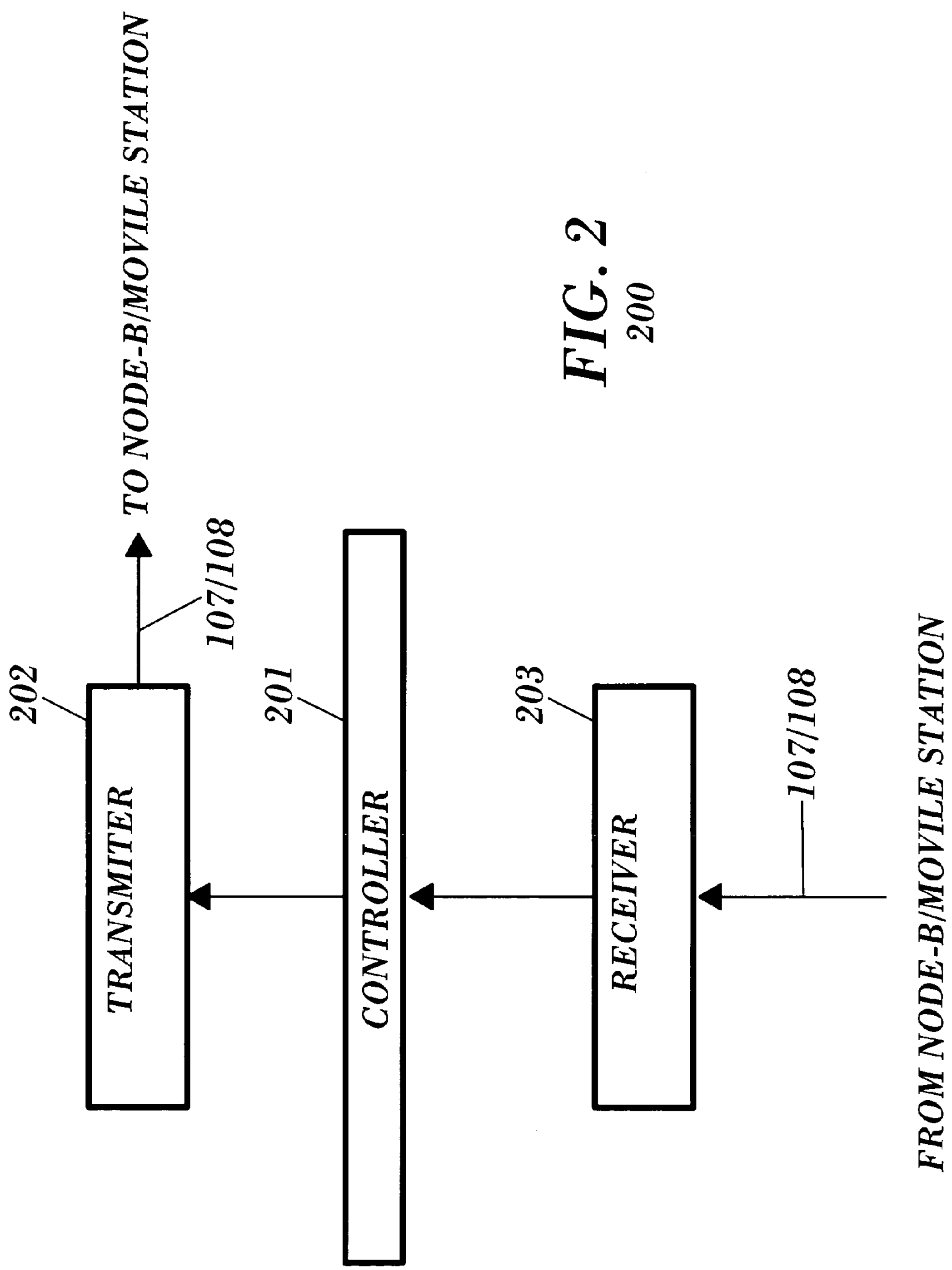

TO NODE-B/MOVILE STATION
107/108
202
TRANSMITER
201
CONTROLLER
203
RECEIVER
107/108
FROM NODE-B/MOVILE STATION

FIG. 2
200

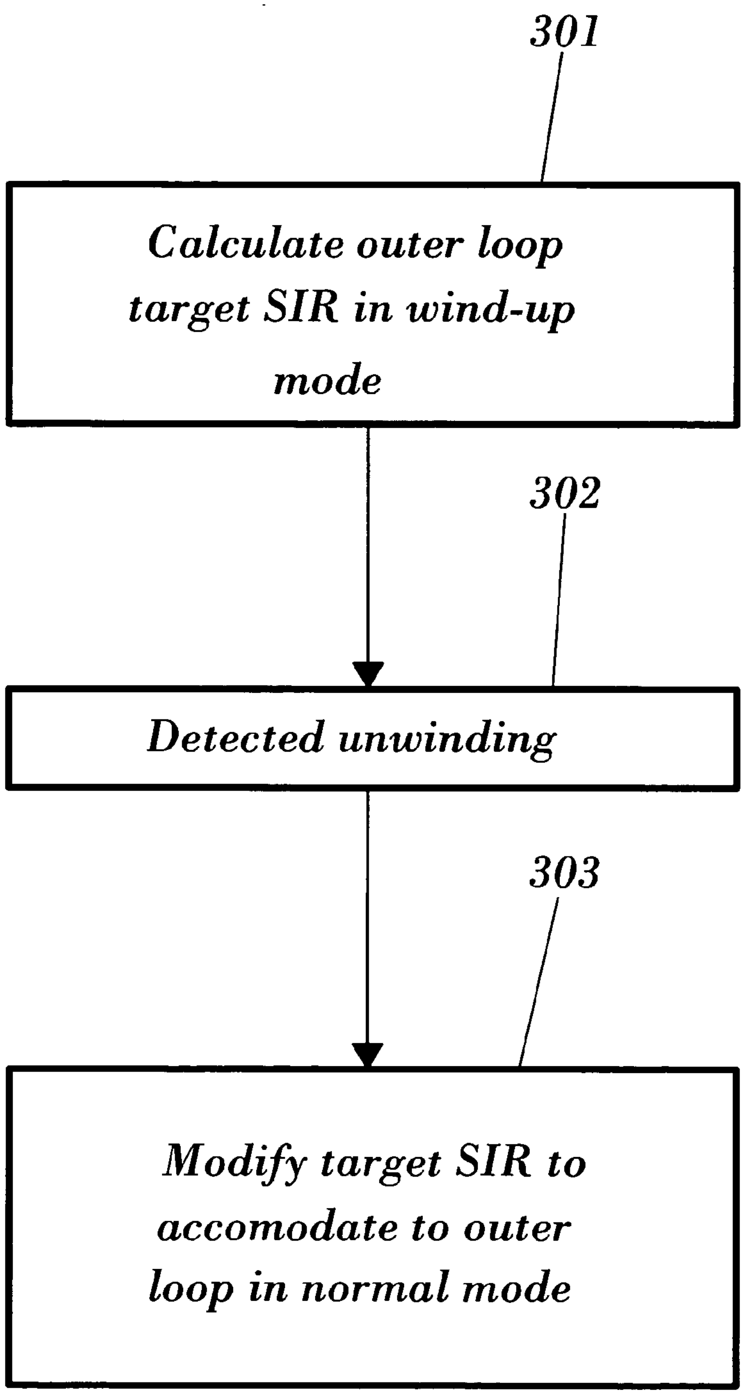

301
Calculate outer loop target SIR in wind-up mode
302
Detected unwinding
303
Modify target SIR to accomodate to outer loop in normal mode

FIG. 3
300

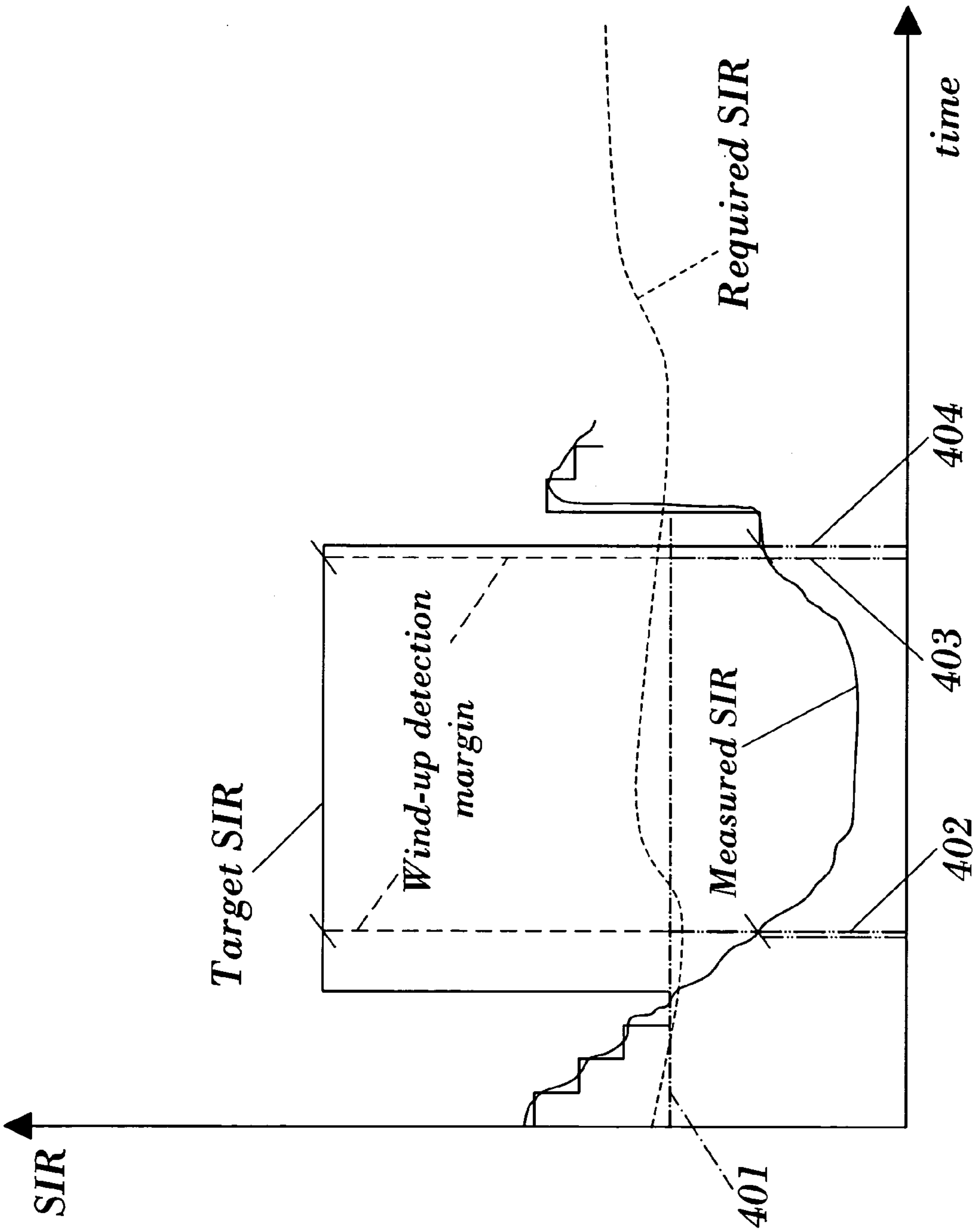

SIR
time
Required SIR
Target SIR
Wind-up detection margin
Measured SIR
401
402
403
404

FIG. 4
400

OUTER LOOP POWER CONTROL METHOD AND DEVICE FOR WIRELESS COMMUNICATIONS SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C § 119 of Spanish patent application Ser. No. 200502057 filed on Aug. 17, 2005, incorporated herein by reference.

OBJECT OF THE INVENTION

This invention has its application within the telecommunications sector and, especially, in the industry dedicated to the manufacture of both base and mobile stations in cellular infrastructures for wireless communications systems.

More specifically, the invention described here refers to a communications method and device for an outer loop power control system in a mobile cellular telephone network.

One purpose of the invention is to allow power control using the outer loop that includes the detection of the normal, wind-up and unwinding operational modes of the outer loop and, in the last, unwinding mode, anticipates the suitable alteration of the target signal/interference ratio to quickly adapt to the outer loop power control function in normal mode.

Reducing the convergence time of the outer loop power control when it exits the wind-up mode and preventing unnecessary interference that reduces the capacity of a wireless communication system when the inevitable wind-up and unwinding phenomena occur are also objectives of the invention.

BACKGROUND OF THE INVENTION

In Jan. 1998 the European Telecommunications Standards Institute (ETSI) chose the basic technology for the Universal Mobile Telecommunications System (UMTS) (see ETSI, "The ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate Submission," June 1998). The main proposed radio interface was the Wideband Code Division Multiple Access (WCDMA) protocol, the features of which offer the opportunity for fully meeting the requirements of third generation (3G) mobile telephony. Because of the high data transmission rate and the increasingly stringent quality of service (QoS) requirements in 3G, the development of new planning strategies were required. These included the power control system, probably that of greatest study, used to implement the outer loop of the system.

The following describes this power control system in general terms since the operation of the outer loop, for which this invention proposes a method, is the result of other components in the system.

The power control system in cellular networks based on WCMDA is required because the technology is limited by interference since all users share the same frequency spectrum and their codes are not completely orthogonal (see Holma & Toskala: "WCDMA by UMTS, Radio Access for Third Generation Mobile Communications," John Wiley & Sons).

The final purpose of the power control system in WCDMA is to obtain the quality of service required in a specific connection, the downlink from the base station to the mobile or terminal, or the uplink from the mobile to the base station, with a minimum level of transmitted power (the precise aspect on which this invention is centred).

The main objectives of the power control system in WCDMA networks are:

Cancellation of the near/far effect: if all the mobile stations were to transmit at the same power without considering the distance or the fading to the base station, the mobiles closest to it would significantly interfere with the terminals further away.

Protection against severe fading.

Minimising the interference in the network with the consequent improvement in capacity.

Longer battery life in the mobile stations.

There are three procedures for implementing a power control system for WCMDA:

By open loop: During the random access process at the start of a connection, the base/mobile station estimates the power loss in the uplink/downlink and adjusts its and transmission power as a function of this.

By closed or inner loop: also called rapid power control (1500 Hz) which consists of the following three steps:

1) The relevant receiver (the base station or the mobile unit) compares the value of the desired signal to interference ratio received (SIR_{rec}) to the desired signal to interference ratio target (SIR_{target}) which depends on the quality of service required for this specific connection and which is set by the outer loop procedure, explained below.

2) The same receiver sends power control bits indicating that the power must be increased (if $SIR_{rec}<SIR_{target}$) or reduced (if $SIR_{rec}>SIR_{target}$) by a certain value (normally 1 dB).

3) The transmitter (base or mobile station) increases or decreases its power by the amount set previously.

By outer loop (OLPC, Outer Loop Power Control): this is much slower than the closed loop (10-100 Hz) and sets the desired signal to interference ratio target (SIR_{target}) to maintain a pre-set quality objective. One criterion or measurement of the quality of a connection is the frame error rate (FER) or its equivalent, the block error rate (BLER), which is a function of the required signal to interference ratio (SIR). Given that the inner loop helps to maintain the desired signal to interference ratio received (SIR_{rec}) close to the target (SIR_{target}), the block error rate (BLER) is, in the end, determined by this target value. Thus, to achieve a quality of service in a specific fading environment, the target (SIR_{target}) must be adjusted to the value that is suitable for this environment.

Sometimes, either because the channel conditions suddenly worsen, so that the receiver does not receive the power control bits sent by the transmitter, or because the transmitter has reached the maximum power available for this connection, the desired signal to interference ratio received (SIR_{rec}) may always be lower than the desired signal to interference ratio target (SIR_{target}).

The result of this situation is that the received frame error rate (FER_{rec}) is greater than the target frame error rate (FER_{target}), that is, that the quality of the connection is degraded. However, this degradation may not be large enough to cut the communication, so that it is maintained albeit with a quality that is less than that desired.

If this occurs—communication continues but at degraded quality—the so-called outer loop wind-up condition or mode may occur: the outer loop power control (OLPC) method will increase the desired signal to interference ratio target (SIR_{target}), to try to reach the target quality criterion, that is, the target frame error rate (FER_{target}), but the desired signal to interference ratio received (SIR_{rec}) will not be able to follow the desired signal to interference ratio target (SIR_{target}) for the

reasons described above (worsening of the channel's conditions or saturation of the transmitter).

In this situation, the outer loop power control (OLPC) method will continue to increase the desired signal to interference ratio target (SIR_{target}) indefinitely to a level much higher than before the sudden worsening of the propagation conditions or the power limitation.

When the conditions subsequently improve or the power limitation disappears, the desired signal to interference ratio received (SIR_{rec}) will finally reach the desired signal to interference ratio target (SIR_{target}), which will then have a much higher value than that for the target frame error rate (FER_{target}). As a result, the received frame error rate (FER_{rec}) being achieved at this point will be much less than necessary and, therefore, will be increasing the interference in the channel, reducing capacity and degrading the quality in other connections.

This undesirable situation will be maintained until the outer loop power control (OLPC) method manages to lower the desired signal to interference ratio target (SIR_{target}) to a suitable value, that is, to that at which the target frame error rate (FER_{target}) is achieved.

This process of lowering the desired signal to interference ratio target (SIR_{target}) after the end of the condition described above, that is, after the wind-up, is called the outer loop unwinding condition or mode and this invention proposes a method for specifically this mode.

The problem is that due to the properties of the outer loop power control (OLPC) algorithm used normally (see Holma H, Toskala A, "WCDMA for UMTS," Wiley, 2002), the process of lowering the desired signal to interference ratio target (SIR_{target}) is very slow. This slow convergence is because the down step size used by the algorithm is, measured in dB, of the order of the target frame error rate (FER_{target}) (typical values are 10^{-2} for the voice service and 10^{-3} for the video calls service), that is, very small, which means that dozens of seconds are needed for each dB decrease.

It is interesting to note that there is a disparity between the down step size and the up step size of the desired signal to interference ratio target (SIR_{target}) fixed by the outer loop power control (OLPC) method. In fact, the up step size is much greater than the down step size: while, as mentioned, the latter is of the order of the target frame error rate (FER_{target}) in dB, the up step size is approximately 1 dB. This fact is relevant because it implies that the outer loop power control (OLPC) method can react quickly to situations requiring an increase in the desired signal to interference ratio target (SIR_{target}) and this is taken into account in this invention.

Because of the above, various answers have been devised to prevent the outer loop power control phenomenon (see US patent application 2003148769). This document proposes the following method for detecting the wind-up: a wind-up situation is declared when the difference between the desired signal to interference ratio target (SIR_{target}) and the desired signal to interference ratio received (SIR_{rec}) exceeds a specific margin or threshold. When the wind-up mode is detected, in US 2003148769, different mechanisms are set up to limit the value of the desired signal to interference ratio target (SIR_{target}) while the wind-up situation lasts. Finally, also in this patent application, criteria are set for detecting the unwinding process, described above, that is, the end of the wind-up, and that starts when the desired signal to interference ratio received (SIR_{rec}) is able to reach the desired signal to interference ratio target (SIR_{target}).

However, in the power control described in US 2003148769, no criterion is set for the unwinding process itself, that is, only a possible form for detecting it is defined but no specific operation of the outer loop in this mode is described; it is assumed to match the normal operating mode of this loop or that of a very slow decrease with the resulting increase in interference in the channel, reduction of capacity and deterioration of the quality of other connections, as explained above.

It should be noted that there is a method to prevent the outer loop wind-up from attenuating the later unwinding process, as achieved in the quoted example of US 2003148769, but it does not prevent it.

DESCRIPTION OF THE INVENTION

This invention is intended to solve the problem described above, among others, in all the aspects described.

The proposed outer loop power control method and device for mobile communications systems, especially designed for third generation (3G) technologies based on some of the standard Code Division Multiple Access (CDMA) protocols modifies the desired signal to interference ratio target (SIR_{target}) when it has exited the wind-up condition, when the unwinding process has started.

More specifically, using the method and apparatus of the invention, at the start of unwinding, the target (SIR_{target}) is made equal to a value suitably close to that which the desired signal to interference ratio target (SIR_{target}) had before the start of the wind-up. This suitable value with which the invention sets this desired signal to interference ratio target (SIR_{target}) when the outer loop power control enters the unwinding mode is as close as possible to the value set for the desired signal to interference ratio target (SIR_{target}) just before it entered the wind-up condition, so that immediately after the outer loop unwinding state ends, the power control follows the variation determined in normal mode.

This suitable changing of the desired signal to interference ratio target (SIR_{target}) by the invention when unwinding starts in the outer loop power control (OLPC) quickly matches the target (SIR_{target}) and, therefore, the power to the outer loop in normal mode.

The reason for changing the desired signal to interference ratio target (SIR_{target}) at the start of the outer loop unwinding situation and making it equal to its closest possible value at the start of the wind-up mode is because, from the start of these wind-up and later unwinding phenomena, the conventional outer loop power control (OLPC) starts to operate defectively. In reality, since wind-up is detected until it ends, the outer loop power control (OLPC) is not allowed to operate in normal mode, that is, the desired signal to interference ratio target (SIR_{target}) is not increased indefinitely. What this invention proposes for the outer loop power control method when it exits wind-up, that is, at the start of unwinding, is to change the desired signal to interference ratio target (SIR_{target}), making it equal to a value as close as possible to its value when the outer loop power control (OLPC) itself ceases to operate in normal mode, that is, just before it enters wind-up.

One aspect of the invention is therefore an outer loop power control method for wireless communications systems which, based on the data signal received from the base or mobile station, involves the following phases:

i) Estimating the desired signal to interference ratio received (SIR_{rec}) based on the data signal from a base or mobile station.

ii) Setting the desired signal to interference ratio target (SIR_{target}) that is close to the desired signal to interference ratio required (SIR_{req}) during the normal mode of the outer loop.

iii) Detecting the start of the outer loop wind-up mode.

iv) Setting a desired signal to interference ratio target (SIR_{target}) during the outer loop wind-up state.

v) Detecting the start of the outer loop unwinding mode.

vi) Changing the ratio of the signal required to interference (SIR_{target}) at the start of the outer loop unwinding, to thus finally match it to the outer loop power control in normal mode.

As a result of the new unwinding mechanism that this invention proposes in the outer loop power control method, the desired signal to interference ratio target (SIR_{target}) thus established at the start of this condition will be as closely as possible equal to the desired signal to interference ratio target (SIR_{target}), suitable for the new propagation conditions, that is, to that which satisfies the relevant target frame error rate (FER_{target}).

Thus, the invention presents a notable improvement over that described in the above mentioned patent application US 2003148769, by considerably reducing the duration time of the unwinding process and, thus, reducing the interference in the communications channel, thus increasing its capacity and the quality of the other connections.

Another aspect of the invention refers to a device for outer loop power control for wireless communications systems that consists of at least one programmable electronic device that operates according to the method described above. The programmable electronic device could be a general purpose processor, a digital signal processor (DSP), an application-specific integrated circuit (ASCI), a programmable card (FPGA) or any combination of these. The general purpose processor could preferably be a microprocessor or other alternatives: a conventional processor, a micro-controller or any general states machine. The programmable electronic device could even consist of a combination of multiple microprocessors, a microprocessor and one or more DSP devices, or any other configuration in which the running of the phases is distributed, in series or in parallel, included in the method described.

Optionally, the proposed outer loop power control device for wireless communications systems could consist of a radio receiver that can receive data signals from the base or mobile station. Additionally, the device could also include a radio transmitter capable of sending the power control information to the relevant base or mobile station. Thus, this outer loop power control device could be built into a wireless communications network controller, or in the user's terminal or mobile in the wireless communications systems.

Some final aspects of the invention involve a radio network controller (RNC) that includes the logic for processing the calls and a mobile station (UE: user equipment or remote terminal), with each device including the outer loop power control device for wireless communications systems as described.

The invention can be applied to any wireless communications system that supports one or more CDMA protocol standards such as WCDMA, IS-95, CDMA2000, the HDR specification, etc.

DESCRIPTION OF THE DRAWINGS

To complement this description and to aid the better understanding of the properties of the invention, according to a preferred example of its practical undertaking, this description is accompanied by a set of drawings that form an integral part of it to illustrate and not limit it, showing the following:

FIG. **1**. Shows part of a mobile communications system, according to the known state of the art, that includes the parts of a cellular infrastructure, mobile user terminal, base station and remote network controller, relating to the object of the invention.

FIG. **2**. Shows a block diagram according to the state of the art, of the part of a base or mobile station with which the invention is concerned.

FIG. **3**. Shows a block diagram with the steps taking place in the base or mobile station controller shown in the previous figure and that correspond to the unwinding method that is the object of the invention.

FIG. **4**. Is a graph of the development of the desired signal to interference ratio target (SIR_{target}) in time, according to the possible undertaking of the invention method, by which there is a margin for detecting the wind-up mode that must be subtracted from the desired signal to interference ratio target (SIR_{target}) at the start of outer loop unwinding mode.

PREFERRED EMBODIMENT OF THE INVENTION

FIG. **1** shows a part (**100**) of a WCDMA mobile communications system. Apart from the invention, the parts shown in the figure are well known and are not described in detail: one part of interest is the user terminal or mobile station (**104**), shown by the vehicle icon; the WCDMA mobile communications system also consists of various base stations (**102**, **103**) or B-nodes in the UMTS network, that contain processors, memories, interface cards and embedded software. This part of the system includes a radio network controller (**101**) or RNC, which, among other functions, provides the call processing. The two base stations (**102**, **103**) and the mobile station (**104**) represent the end points of the wireless interface. Each base station (**102**, **103**) is associated with an RNC (**101**) via land lines (**105**, **106**). In the following, it is assumed that the mobile station (**104**) is communicating with the base station (**102**) via the downlink data signal (**107**) and the uplink data signal (**108**).

FIG. **2** shows the part (**200**) of both stations, base station (**102**) and mobile (**104**), that includes the principles on which this invention is based. The known aspects of the elements shown in the figure are not described since a radio transmitter (**202**) and receiver (**203**) are described in detail in the state of the art. Both the base station (**102**) and the mobile (**104**) contain a controller (**201**), a transmitter (**202**) and a receiver (**203**). Thus, in the case of the base station (**102**), the signal received is the uplink (**108**) and in the case of the mobile (**104**), the signal received is the downlink (**107**). Both reach the controller (**201**) via the receiver (**203**). The power control device that forms the object of the invention is built into the controller (**201**) and sends a command via the transmitter (**202**) that indicates to the receiver station at the time that it increases or reduces its power, depending on the result of the outer loop power control method described below, in order to set the desired signal to interference ratio target (SIR_{target}) that acts as the threshold in the closed power control loop.

The outer loop power control method of the invention includes mechanisms to detect the wind-up situation, so that once it is detected, the outer loop abandons the normal mode and passes top operation in wind-up mode, as can be seen in FIGS. **7** and **8** of the prior patent application US2003148769, using outer loop power control algorithms known in the different situations: normal mode and wind-up.

Likewise, the method that forms the object of the invention includes mechanisms to detect the end of this wind-up phenomenon, that coincide, for the definition given earlier, with the start of the unwinding process.

Following the progress of these phenomena, after abandoning normal mode and in order to return to the power level that gives a desired signal to interference ratio target (SIR_{target}) that is suitable for outer loop power control in normal mode, the steps that take place, in accordance with that which forms the object of the invention, in the controller (**201**) are those shown in the diagram (**300**) in FIG. **3**. The desired signal to interference ratio target (SIR_{target}) in wind-up mode is calculated in the block (**301**), using known algorithms; next, an unwinding detector (**302**) is able to determine the end of the wind-up and the start of the unwinding, and the modification of the desired signal to interference ratio target (SIR_{target}) takes place in the final block (**303**), so that it arrives at a value that is suitable for the outer loop power control operating in normal mode. The modification of this desired signal to interference ratio target (SIR_{target}) at the start of the unwinding is the object of this invention and is shown in FIG. **4**, explained below.

At the start of the unwinding condition in the evolution of the power control in time, this starting point being detected as the end of the wind-up condition and also previously detected by a known mechanism such as that described in patent application US2003148769, the method that forms the object of the invention changes the desired signal to interference ratio target (SIR_{target}), giving it a value that is equal or as close as possible to the original value (**401**) that it had just before the moment that the outer loop wind-up started (**402**). This value (**401**) is the last correct value of the desired signal to interference ratio target (SIR_{target}) set before stopping the running of the outer loop power control in normal mode, so that immediately after the wind-up situation is left, the variation of the desired signal to interference ratio target (SIR_{target}) continues and, therefore, that of the power level determined by the normal mode of the outer loop.

Referring now to FIG. **4**, the last correct value (**401**) is considered to be that of before the wind-up situation. During the wind-up, the value of the desired signal to interference ratio target (SIR_{target}) is incorrect because the mechanisms that operate during the wind-up mode limit or cancel the outer loop power control so that the desired signal to interference ratio target (SIR_{target}) does not continue to grow indefinitely. FIG. **4** also shows, with a dotted line, the desired signal to interference ratio required ($SIR_{required}$), defined as a theoretical minimum of the desired signal to interference ratio received (SIR_{rec}) that satisfies the target frame error rate (FER_{target}). A continuous line also shows the desired signal to interference ratio measured ($SIR_{measured}$) which is the real estimate of the desired signal to interference ratio received (SIR_{rec}), made mainly by the controller (**201**) of the base or mobile station in the network radio.

To choose this last correct value (**401**) for the desired signal to interference ratio target (SIR_{target}), the invention's method proposes the following mechanism, preferentially applicable if the wind-up detection has been planned using a detection margin (M) between the desired signal to interference ratio target (SIR_{target}) and the desired signal to interference ratio received (SIR_{rec}), as specified in FIG. **4**. In this case, the detection of the wind-up situation by the detector (**302**) occurs at the starting point (**402**) of the outer loop wind-up. Later, this detector (**302**) also determines the end of the wind-up mode and thus detects the starting point (**403**) of the unwinding. At this point (**403**), this mechanism reduces the desired signal to interference ratio target (SIR_{target}) by the same amount as the detection margin (M). This mechanism thus allows the value of the desired signal to interference ratio target (SIR_{target}) to return to a value that is very close to the original value (**401**) it had at the point before the start (**402**) of the wind-up.

As shown in the graph (**400**) in FIG. **4**, at the point (**404**) immediately after the start (**403**) of the unwinding, the value of the desired signal to interference ratio target (SIR_{target}) obtained after subtracting the detection margin (M) from the value set (**406**) during the wind-up, which could be fixed or variable within a limit according to the wind-up mechanism applied, is slightly below the desired signal to interference ratio required ($SIR_{required}$), which implies a slight loss of quality in the channel, but this reduction of quality will be very short since, as already mentioned, the known stepping algorithm of the outer loop power control is very fast when it is necessary to increase the desired signal to interference ratio target (SIR_{target}). On the other hand, this slight, brief loss of quality is not noticed by the end user, since he has been with an even more degraded quality during his communication throughout the wind-up phenomenon, for example, if the user has entered a lift while talking on his mobile telephone. Any reduction that is greater or less than this detection margin (M) is considered covered by this invention.

The great advantage of the new unwinding mechanism that includes the method proposed for wireless communications systems is that it drastically reduces the convergence time of the outer loop power control on exiting the wind-up state and, thanks to it, prevents unnecessary interferences that reduce the system's capacity.

The above design has been used to describe the principles of the invention; however, other alternatives, although not detailed here but which incorporate the same spirit and purpose, are possible. For example, although the invention has been illustrated here with discrete functional blocks that can be run in the controller (**201**) of a wireless communications network, the functions of any of these blocks can be carried out using one or more suitably programmed processors.

In the same line, the invention is applicable to other standards apart from WCDMA, for power control of any signal received both by the base stations and by users' terminal equipment or mobile stations.

The terms in which this description has been prepared must always be taken in the wide and non-limiting sense.

What is claimed is:

1. Outer loop power control method for wireless communications systems, based on CDMA technology, the method comprising:

estimating a desired signal to interference ratio received (SIR_{rec}) based on a data signal (**107**, **108**) received from a base station (**102**, **103**) or mobile station (**104**),

setting a desired signal to interference ratio target (SIR_{target}) that is close to a signal to interference ratio required (SIR_{rec}) during the normal mode of the outer loop,

detecting a start (**402**) of the outer loop wind-up,

setting a specific desired signal to interference ratio target (SIR_{target}) during the outer loop wind-up, and

detecting a start (**403**) of the outer loop unwinding,

wherein the desired signal to interference ratio target (SIR_{target}) is modified at the start (**403**) of the outer loop unwinding, to match it to the outer loop power control in normal mode just prior to the start of the outer loop wind up.

2. Outer loop power control method for wireless communications systems, according to claim **1**, wherein at the start (**403**) of the outer loop unwinding the desired signal to inter-

ference ratio target (SIR_{target}) is set to a value suitably close to the original value (**401**) set just before the start moment (**402**) of the outer loop wind-up.

3. Outer loop power control method for wireless communications systems, according to claim **1**, wherein the start (**402**) of the outer loop windup is detected when the difference between the desired signal to interference ratio target (SIR_{target}) and the desired signal to interference ratio received (SIR_{rec}) exceeds a specific detection margin (M) of the outer loop wind-up.

4. Outer loop power control method for wireless communications systems, according to claim **3**, wherein at the start (**403**) of the outer loop unwinding, the detection margin (M) is subtracted from the desired signal to interference ratio target (SIR_{target}) set at the start (**402**) of the windup detected in the outer loop.

5. An outer loop power control device for wireless communications systems, comprising at least one programmable electronic device, the programmable electronic device operable to perform the steps of:

estimating a desired signal to interference ratio received (SIR_{rec})based on a data signal (**107**, **108**) received from a base station (**102**, **103**) or mobile station (**104**),

setting a desired signal to interference ratio target (SIR_{target}) that is close to a signal to a signal to interference ratio required (SIR_{req}) during the normal mode of the outer loop,

detecting a start (**402**) of the outer loop wind-up,

setting a particular desired signal to interference ratio target (SIR_{target}) during the outer loop wind-up, and

detecting a start (**403**) of the outer loop unwinding,

wherein the desired signal to interference target (SIR_{target}) is modified at the start (**403**) of the outer loop unwinding, to match it to the outer loop power control in normal mode just prior to the start of the outer loop wind up.

6. Outer loop power control device for wireless communications systems, according to claim **5**, wherein the programmable electronic device is chosen from among a general purpose processor, a digital signal processor (DSP), an application-specific integrated circuit (ASCI) and a programmable card (FPGA) or any combination of these.

7. Outer loop power control device for wireless communications systems, according to claim **5**, further comprising a radio receiver (**203**) able to receive a data signal (**107**, **108**) from a base station (**102**, **103**) or from a mobile station (**104**) of the wireless communication system.

8. Outer loop power control device for wireless communications systems, according to claim **5**, further comprising a radio transmitter (**202**) able to send the power control information to a base station (**102**, **103**) or to a mobile station (**104**) of the wireless communication system.

9. Outer loop power control device in a wireless communication system, according to claim **5**, wherein the outer loop power control device is incorporated in a wireless communications network controller.

10. Outer loop power control device in a wireless communication system, according to claim **5**, wherein the outer loop power control device is incorporated in a mobile station for wireless communications systems.

11. A radio network controller for wireless communications systems including the outer loop power control device according to claim **5**.

12. Mobile station for wireless communications systems including the outer loop power control device according to claim **5**.

* * * * *